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EFFECTS OF THE STOCKTON SHIP CHANNEL DEEPENING ON THE HYDRAULICS AND WATER QUALITY NEAR THE PORT OF STOCKTON, CALIFORNIA

prepared by

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CHAPTER I

INTRODUCTION

I.1 BACKGROUND

The Sacramento District of the U.S. Army Corps of Engineers (Corps) is presently in the process of dredging the Stockton Ship Channel to a recently authorized depth of 35 feet below mean lower low water.

The channel deepening will increase the channel flow area resulting in lower flow velocities. The lower velocities will increase the time required for the flow to pass through the project area. The lower velocity coupled with the increased depth will tend to reduce the rate of oxygen reaeration.

Because of turbidity levels typically found in the Ship Channel and Delta channels, the euphotic zone (i.e., the layer with sufficient light for photosynthesis) does not reach the bottom of the deeper channels. Since the euphotic zone fraction of the total water body will be reduced by the channel deepening, it is believed that dissolved oxygen uptake by phytoplankton will increase in the Ship Channel.

The increased hydraulic residence time, reduced reaeration and increased oxygen uptake by phytoplankton could all contribute to lower oxygen in the Stockton Ship Channel and adjacent Delta waters. Historically, low dissolved oxygen levels have been observed in the channel near Stockton and these reductions have had an adverse effect on fish populations which migrate through or reside in this portion of the Delta.

To quantify the effects of the channel deepening on dissolved oxygen concentrations, the Corps contracted with Resource Management Associates (RMA) to develop a link-node model representation of the Delta capable of simulating hydrodynamic and water quality conditions.

I.2 SCOPE OF WORK

The project is composed of two major components; the hydrodynamic and the water quality evaluation. The hydrodynamic evaluation includes the following tasks:

1. Set up a link-node network representation of the Sacramento-San Joaquin Delta system. The network representing the Port of Stockton and Ship Channel shall be of sufficient detail to provide good spacial definition of the hydrodynamic and water quality effects of the channel deepening.

2. Calibrate and validate the hydrodynamic model to historical stage data.

3. Evaluate effects of ship channel deepening on the hydraulic characteristics of the Delta channels using the calibrated model.

4. Perform hydrodynamic simulation for the test years using the calibrated model, and store the results for use as input to the water quality modeling.

The water quality evaluation included the following tasks:

1. Develop a water quality simulation procedure for the link-node representation of the Sacramento-San Joaquin River Delta system.

2. Calibrate and validate the water quality model to historical dissolved oxygen data, using two different test periods.

3. Evaluate the water quality model sensitivity to key input parameters, such as:

   a) inflow quality
   b) depth of light penetration
   c) benthic Biochemical Oxygen Demand
   d) phytoplankton and detritus fluctuations
   e) various reaction rate constants

4. Evaluate the effects of channel deepening by performing water quality simulation for the two test periods using the calibrated model. This analysis shall use a modified link node representation based on 1982 sounding data with Ship Channel cross-section depths of 30 and 35 feet.

5. Estimate the amount of forced aeration required to balance any reduction in DO levels caused by channel deepening.

I.3 PROJECT ORGANIZATION AND ACKNOWLEDGEMENT

The study was conducted under the supervision of Mr. D. J. Smith of RMA and was assisted by Ms. Lisa Roig in model production runs and in the report preparation. Mr. George Nichol served as project manager for the Corps and provided project guidance and coordinated the data collection effort.

CHAPTER II

SUMMARY

II.1 PROJECT GOALS

The primary purpose of the study was to evaluate the effect of deepening the Stockton Deep Water Ship Channel on the hydraulics and water quality in the area of the Port of Stockton. Dissolved oxygen concentrations were the main water quality concern. This evaluation was accomplished using a link-node hydrodynamic and water quality model tailored to the project needs. The major components of the project were:

1. Modification of the computer code to meet the specific and unique requirements of the study.

2. Development of a model representation of the ship channel and adjacent Delta channels

3. Calibration and validation of the hydrodynamic and water quality models.

4. Evaluation of the models sensitivity to various model parameters.

5. Evaluation of the impact of the deeper ship channel on the hydraulics and water quality in the area of the Port of Stockton.

6. Estimation of the amount of forced aeration required to balance the reduced DO levels caused by channel deepening.

II.2 PROGRAM MODIFICATIONS

Modification of the hydrodynamic model computer code included provision for continuous tidal condition update, variable Clifton Court withdrawals, efficient input of channel depletions and more extensive output to aid in the interpretation of model results. Major modifications of the water quality model computer code included the addition of the significant water quality parameters and interaction which control the dissolved oxygen resources of the Ship Channel near the Port of Stockton, and a procedure to minimize numerical dispersion by adjusting the internode mass transfer rate based on hydraulic residence time. These model improvements are discussed in detail in the program documentation (1) prepared for this project.

II.3 MODEL REPRESENTATION

The Stockton Ship Channel network was designed to provide a detailed representation of the Stockton Ship Channel and adjacent Delta channels and less detail further from the project site. The network was extended beyond the limits of the immediate study area to eliminate the need for specifying the flow rate and quality of the channels entering the Stockton Ship Channel. With this network, the flows and quality entering the ship channel are computed based on boundary conditions specified far away from the project site, thereby greatly reducing the possibility of biasing the results by improper boundary condition specification.

II.4 HYDRODYNAMIC CALIBRATION AND VALIDATION

The hydrodynamic model calibration was accomplished using data for a five day high flow period in June 1978 and a fifteen day low flow period in September 1974. These two periods were selected to ensure that the model represented a wide range of hydraulic conditions. During the calibration process, the Mannings roughness coefficient for selected channels were adjusted until good agreement was reached between the computed and observed tidal stage throughout the Delta. The final roughness coefficients for the calibrated model were within the generally accepted range for slow moving natural and man-made channels and ranged from 0.025 for well maintained straight channels to 0.045 for the more natural meandering channels.

The hydrodynamic model validation utilized a 15 day period in the Fall of 1978. The calibrated model was run without altering any roughness coefficient or channel geometry. Good agreement between the computed and observed tidal stage was reached at all locations.

Reasonable agreement between the computed and the DWR estimated flows at the Old River-San Joaquin bifurcation and Delta cross-channel and Georgiana Slough was observed for both the calibration and validation periods.

The good agreement between the simulation results and the observed tidal stage and estimated flows during the calibration and validation periods indicated the model was adequately calibrated and ready to evaluate the hydrodynamic effects of the channel deepening.

II.5 QUALITY CALIBRATION AND VALIDATION

The period September 1 through September 26, 1974, was selected for water quality model calibration. Model calibration was performed using observed DO concentrations in the San Joaquin River and Stockton Ship Channel measured by the DWR and by the City of Stockton.

For calibration the inflow quality of the San Joaquin River and other major tributaries was based on one or two measurements taken during the month of September. The Stockton waste water facility effluent was based on plant operation data. Because of the sparse data set, no attempt was made to vary the quality of any of these inflows during the calibration.

The calibrated model does not match extreme variations observed during the test period due in part to the use of average inflow conditions. Rather, the model was calibrated to approximate average conditions in the Stockton Ship Channel. No attempt was made to match the variable DO profile since there was not sufficient inflow data to justify variation within the calibration period.

The calibrated model was validated using the September 26, 1978 to October 10, 1978 test period by running the model for the 15 day period without varying any model parameters. Again, the inflow quality of the San Joaquin River and other major tributaries was based on one or two measurements taken during this period. The model results match observed DO ranges well over the entire validation period. The match beween the computed and observed DO values was much better for the validation than for the calibration period. The better match was due in part to the smaller variation in the hydrology and other environmental conditions.

Additional water quality parameters simulated by the model were not calibrated due to insufficient data; however, predicted concentrations for nitrate-nitrogen, orthophosphate-phosphorous, total coliform, detritus, ultimate carbonaceous BOD, ammonia-nitrogen, diatoma, and other algal species were within the ranges typically observed during September and October in the Stockton Ship Channel.

For both the hydrodynamic and quality calibration and verification described above the 1977 channel geometry soundings were used. These data were the closest in time to the 1974 and 1978 hydraulic and water quality simulation periods.

II.6 MODEL SENSITIVITY

The intent of the sensitivity analysis was to determine the magnitude of the effect of various environmental factors on the model representing the dissolved oxygen resources. Based on a good understanding of what affects DO in the Delta and experience gained in the calibration phase of this project, the models sensitivity to the depth of light penetration, benthic BOD, Stockton wastewater facility effluent quality, San Joaquin River quality upstream of Stockton, DO coupling with phytoplankton and detritus, and method of calculating inflow estimates were examined.

Sensitivity analyses were carried out for the September 26 - October 10, 1978 test period. 1977 channel geometries were used.

The sensitivity analysis confirmed that the dissolved oxygen resources in the ship channel are significantly influenced by phytoplankton growth and respiration and detritus decay. The quality of the San Joaquin River and Stockton wastewater facility effluent which were the major sources of phytoplankton and detritus therefore have the greatest influence on dissolved oxygen within the ship channel.

This analysis also showed the benthic BOD is only a minor contributor to the DO sag in the ship channel.

II.7 IMPACT OF SHIP CHANNEL DEEPENING

The evaluation of the effects of channel dredging utilized two revised sets of model geometry which were based on the Corps' 1982 soundings. For pre-dredging conditions the channel cross sections were truncated at 30 feet. This was done even though many pre-dredging depths were deeper than 30 feet due to previous overdepth maintenance dredging. The authorized pre-dredging depth of 30 feet was used in modeling because this was an approved depth against which effects could justifiably be compared. To represent post-dredging conditions, the 35 foot dredge template was superimposed. Other delta channels were not altered in either of these model representations.

Both the hydrodynamic and water quality effects of channel deepening were evaluated. The channel deepening had no detectable effect on the tidal stage at any location within the Delta. Velocities in the turning basin and ship channel, however, were typically reduced 10% due to the increased cross section area. Because of the reduced velocity and increased depth, the reaeration rate calculated using the O'Connor and Dobbins relationship was reduced typically 20%. Net flows in the ship channel and all hydraulic parameters elsewhere in the Delta were virtually unaffected by the channel deepening.

Channel deepening contributes to the DO sag by reducing velocities and reaeration and decreasing the euphotic zone fraction of the water column. To quantify these effects of channel deepening, the water quality model was run for both the September-October 1978 period and the September, 1974 period, using 1982 geometries and hydrodynamic simulation results for the 30 foot and 35 foot deep ship channel. In each case, the maximum reduction in DO due to the deeper channel was approximately 0.5 mg/L.

Many of the channels are already deeper than the 30 foot authorized depth, therefore the actual reduction in DO due to deepening to 35 feet from the existing condition would be less. The maximum reduction due to dredging relative to existing conditions was approximately .25 mg/L.

II.8 DISSOLVED OXYGEN REQUIREMENTS FOR REVERSAL OF DREDGING EFFECTS

In order to balance the reduced oxygen levels predicted for the dredged channel, oxygen could be added to the ship channel system. Several alternatives are available to increase oxygen levels in the ship channel including flow alteration and mechanical aeration.

Determination of the most feasible method for oxygen enhancement however, is beyond the scope of this contract.

To provide and estimate for the amount of additional oxygen needed to counter the effects of the deeper ship channel, the model was run for the dredged channel configuration and a total of 7500 pounds of oxygen added per day to a limited reach of the Stockton Ship Channel. The area of forced oxygen input was bounded by river miles 33 and 38 (nodes 21-25) and coincided with the area of maximum computed sag on October 10, 1978. The 7500 pounds of oxygen added by induced aeration increased the daily average minimum DO approximately 1.1 mg/L from 4 mg/L to 5.1 mg/L for 1978 test period. Assuming the increase is proportional to the amount of oxygen input over the 1.1 mg/L range, approximately 3400 pounds of oxygen per day would be required to counter the .5 mg/L reduction in DO caused by the increased depth in the Stockton Ship Channel.

Proper management will be important in prescribing an aeration plan. This fact is demonstrated by the simulation results for September 26, 1974, which indicates an addition of 7500 pounds of oxygen per day between river miles 33 and 38 would result in an increase in the minimum DO of only .65 mg/L. The effect of aeration was less pronounced since the low point in the DO sag occurred further downstream due to larger net San Joaquin River flows. Forced aeration would be the most effective if the location and intensity could vary with the hydrology conditions to coincide to the region of maximum DO depression.

CHAPTER III

REPRESENTATION AND APPLICATION OF THE SACRAMENTO-SAN JOAQUIN DELTA MODEL

III.1 INTRODUCTION

RMA's link-node hydrodynamic model represents the estuarine system as a variable grid network of "nodes" and "channels" (i.e., links). Nodes are discrete volume units of waterbody, characterized by surface area, depth, side slope and volume. The nodes are interconnected by channels, each having associated length, width, cross-sectional area, hydraulic radius, side slope and friction factor. Water is constrained to flow from one node to another through these defined channels. The associated quality parameters (i.e., heat and biotic and abiotic materials) are assumed to be passively transported with the water movement through these channels.

The hydrodynamic program performs a numerical integration of the equation of motion and the equation of continuity, stepping forward in time. The water quality program integrates a series of interdependent and coupled differential equations derived from the principle of conservation of heat and mass and the specific response of each parameter. The results are time histories of velocities and flows in each channel and the water surface elevation and the quality parameters concentration and temperature at each node.

The procedure and consideration for selecting the node and channel representation of the prototype, the theory of one-dimensional fluid flow, the relationships affecting each of the quality parameters and the input data required by both programs can be found in the users manual (1) prepared for the Stockton Ship Channel study.

III.2 STOCKTON SHIP CHANNEL LINK-NODE NETWORK

The Stockton Ship Channel network shown on Figure III-1 was designed to provide a detailed representation of the Stockton Ship Channel, Turning Basin, and adjacent Delta channels and less detail further from the project site. The network extends beyond the limits of the immediate study area to eliminate the need for specifying the flow rate and quality of the channels entering the Stockton Ship Channel. With this network, the flows and quality entering the channel are computed based on boundary conditions specified far away from the project site (i.e., sea boundary at Antioch, San Joaquin River at Mossdale, etc.). By including most of the Delta in the network the possibility of biasing the results by boundary condition specification has been greatly reduced.

The network utilized elements of the existing "Delta Coarse Grid Network" which was developed by the State Department of Water Resources and others (2). This network was based on navigational chart data and measured cross-section and has been shown to give a good representation of Delta hydraulics.

In the immediate vicinity of the Stockton Ship Channel, many channels and nodes were added to provide a gradual transition between the coarse grid and the detailed ship channel grid. As with the coarse grid network, navigational charts and cross-section data were used to define the network geometry.

For the channel and node geometry representing the ship channel, the cross sections based on 1977 and 1982 channel soundings were used. The sounding transects were taken at intervals of approximately 400 feet along the length of the Ship Channel. One to five representative transects per mile were selected by Corp personnel and plotted. These cross-section locations are shown on Figure III-2 and the plotted cross sections are shown in Appendix A. To represent post dredging conditions the 35 foot dredge template was superimposed on the 1982 channel cross sections. A 40 foot template was used for the sections at river miles 39.34 and 39.57 to represent the settling basin (i.e., sediment trap). The sounding transects data were all referenced to the "zero sounding line" which coincides to mean lower low water at the site. The sounding depths were corrected to mean sea level (MSL) datum by adding a correction of 1.1 feet (e.g., 35 feet below zero sounding = 36.1 feet MSL). Table III-1 shows the cross section area below the zero sounding line for 1977 and 1982 conditions. The cross section area for 1982 conditions truncated to the 30 foot depth, and the 35 foot dredge template (35 and 40 feet in the settling basin) were used to evaluate the effects of channel deepening.

The actual channel and node geometry data developed for the Stockton Ship Channel project can be found in the users guide.(1)

III.3 DELTA HYDROLOGY

The hydrologic data required by the hydrodynamics model includes point and nonpoint inflows to and withdrawals from the Delta channels, evaporation losses and the imposed tide at the seaward boundary.

Major inflow to the Delta includes the Sacramento River (node 65), San Joaquin River (node 163), Mokelumne River (node 89) and the City of Stockton's waste water discharge (node 158). Major withdrawals include the Delta Mendota Canal (node 144), the California Aqueduct (node 151) and the Contra Costa Canal (node 123). Many other smaller inflows and withdrawals result from agricultural, municipal and industrial uses. These smaller inflow and withdrawals have been lumped along with net evaporation into a single value referred to as channel depletion. The channel depletion is based on many years of experience and spot measurements by the DWR of various inflows and withdrawals. The total channel depletion which varies on a daily basis is composed of a highland component (39%) and a lowland component (61%). The channel depletion is allocated to each node by means of a lowlands and highlands channel depletion ratio and are summarized in the users guide.(1)

The major inflows and withdrawals and the net channel depletions are summarized on a daily basis in the DWR's "Dayflow Summary" (3) for water years 1935 through 1980. The Dayflow Summary served as the source of all inflow and withdrawal data with the exception of the City of Stockton's waste water discharge rate which was obtained from plant operation reports.

The DWR maintains continuous tidal stage recorders at numerous locations throughout the Delta (see Figure III-1). These records are processed and presented in tabular form as stage and time pairs at 15 minute intervals. These records were used to define the stage at the seaward boundary (Antioch) and at other locations inland for evaluating model accuracy.

III.4 DELTA WATER QUALITY

The water quality model simulates temperature and the following water quality parameters:

1. Dissolved oxygen
2. Carbonaceous BOD
3. Detritus (non living particulate organic material)
4. Ammonia nitrogen (nitrogenous BOD)
5. Nitrate nitrogen
6. Phosphate phosphorus
7. Phytoplankton Type 1 (diatoms)
8. Phytoplankton Type 2 (greens and others)
9. Coliform Bacteria
10. Total Dissolved Solids

The interaction and coupling between these water quality parameters is shown in Figure III-3. The concentration of each parameter is computed at hourly intervals. Some of these parameters are measured directly at various locations within the Delta while others must be estimated based on indicated parameters (e.g., Phytoplankton based on Chlorophyll a) and a knowledge of the inflow or location. The procedure used to estimate model parameters from indicator parameters is as follows:

Phytoplankton - 100 times the chlorophyll a measurement. (The ratio of algal biomass to chlorophyll a ranges from 25 to 150 (5) and is normally near 100)
- 60% of the volatile solids measured in the City of Stockton waste water effluent. (Diatom were assumed dominant in all inflows except for the City of Stockton discharges where green and others were assumed to dominate.)

Detritus - 100 times the pheophyton a measurement.
- 40% of the volatile solids measured in the City of Stockton waste water effluent.

Phosphate P - Dissolved ortho phosphorus

Water quality data required by the water quality model includes initial conditions at each node, system coefficients at each node, quality conditions at the seaward boundary, quality inflows, and meteorological data.

Initial quality conditions for the Delta were derived from STORET data, DWR data reports, and supplemental data from state and local sources. Sampling stations in the Delta are spaced more widely than nodes in the model representation. Therefore, data from one sampling station were applied over a zone of nodes. Techniques of data collection and analysis vary between contributing agencies, yielding variable results. Often only one or two data points exist for the entire test period. To overcome the space quality data set, average September conditions were simulated for approximately 20 days and the results were used as initial conditions for all quality evaluations. The subsequent quality simulations were run for at least 15 days to avoid biasing the results by these initial condition data.

Water quality conditions in the Delta are influenced by 4 major inflows. The San Joaquin River drains the heavily irrigated San Joaquin Valley. San Joaquin River quality in September is high in dissolved solids, nitrates and phosphates and is a major source of diatoms to the Delta system. Biochemical oxygen demand in the San Joaquin River is also high for a natural river.

The quality of the Sacramento River and the Mokelumne River are very similar and superior to that of the San Joaquin River. The concentration of dissolved solids, nutrients, phytoplankton and BOD in the San Joaquin are generally many times greater than those observed in these two northern inflows. Dissolved oxygen is about 8 mg/L in all three rivers as they enter the Delta.

The fourth major inflow from a quality standpoint is the Stockton Regional Waste Water Control Facility. The effluent is released at river mile 42 approximately two miles upstream of the ship channel. The Stockton STP effluent was high in volatile suspended solids which were assumed to be green algae and detritus and often low in dissolved oxygen. The treatment plant has been upgraded to reduce the effluent BOD and volatile solids since the 1978 model validation period.

The withdrawals for the Delta Mendota Canal and California Aqueduct also have a significant effect on the quality of the waters of the Delta and the Stockton Ship Channel. These withdrawals create a net southward flow of Sacramento River water which intercepts the seaward flow of the poorly oxygenated water in the Ship Channel and draws it south. During periods of significant pumping, this southward flow limits the progression of the poor quality San Joaquin River water to the vicinity of Medford Island. Pumping also tends to reduce the net seaward flow in the San Joaquin River and ship channel by drawing water west through Old River. The reduced net flow tends to exacerbate the quality problems of the ship channel by reducing the flushing rate.

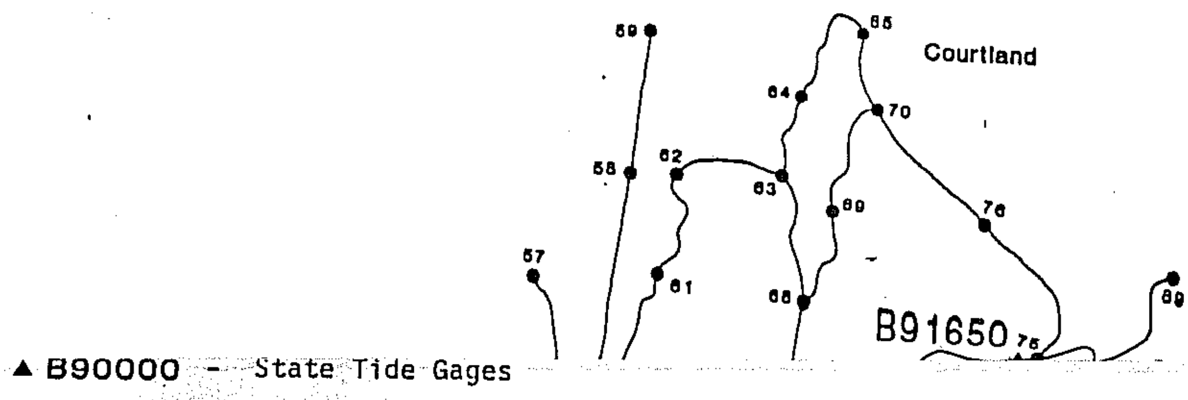
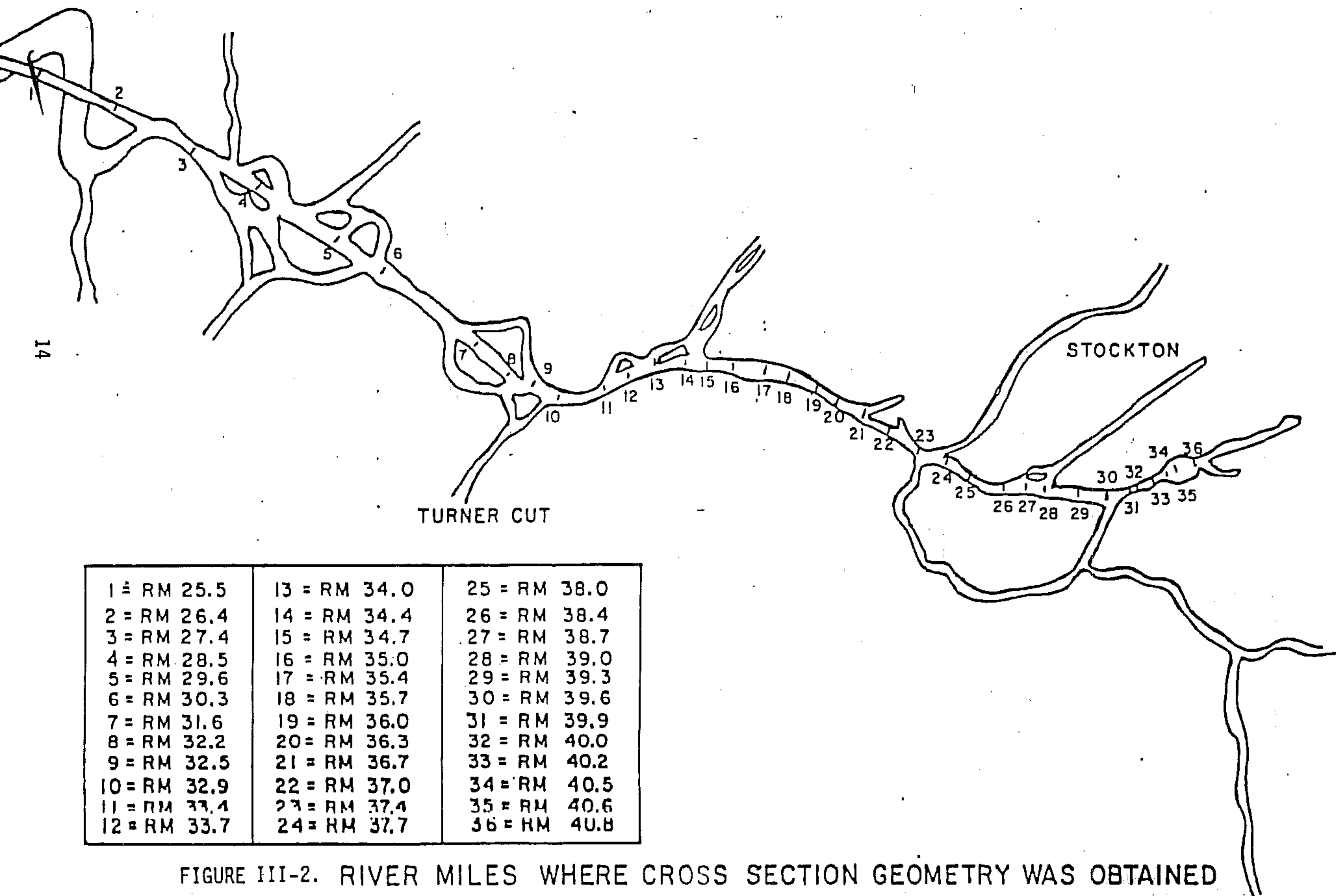


FIGURE III-1

LINK-NODE MODEL REPRESENTATION OF THE DELTA



1 = RM 25.5	13 = RM 34.0	25 = RM 38.0
2 = RM 26.4	14 = RM 34.4	26 = RM 38.4
3 = RM 27.4	15 = RM 34.7	27 = RM 38.7
4 = RM 28.5	16 = RM 35.0	28 = RM 39.0
5 = RM 29.6	17 = RM 35.4	29 = RM 39.3
6 = RM 30.3	18 = RM 35.7	30 = RM 39.6
7 = RM 31.6	19 = RM 36.0	31 = RM 39.9
8 = RM 32.2	20 = RM 36.3	32 = RM 40.0
9 = RM 32.5	21 = RM 36.7	33 = RM 40.2
10 = RM 32.9	22 = RM 37.0	34 = RM 40.5
11 = RM 33.4	23 = RM 37.4	35 = RM 40.6
12 = RM 33.7	24 = RM 37.7	36 = RM 40.8

FIGURE III-2. RIVER MILES WHERE CROSS SECTION GEOMETRY WAS OBTAINED

Table III-1

SHIP CHANNEL CROSS-SECTION AREAS
SQ FT 1/ 2/

RIVER MILE	FOR CALIBRATION AND VERIFICATION 1977 SOUNDING	1982 SOUNDING	FOR PROJECT PREDICTIONS: 1982 SOUNDINGS TRUNCATED TO 30-FOOT DEPTH	FOR PROJECT PREDICTIONS: 1982 SOUNDINGS TRUNCATED TO 35-FOOT DREDGE TEMPLATE
25.5	3/	16,958	13,698	14,898
26.4	3/	15,740	13,330	14,555
27.4	3/	21,500	19,482	20,707
28.5	3/	25,188	24,139	25,314
29.6	3/	11,500	11,644	12,819
30.3	3/	17,826	16,580	17,755
31.6	3/	14,250	13,506	14,731
32.21	13,000	12,713	11,942	13,127
32.50	16,241	14,482	14,124	15,849
32.97	14,838	14,536	13,536	14,867
33.39	14,764	14,990	13,995	15,391
33.73	13,534	13,810	13,301	15,317
34.03	13,100	12,302	11,545	13,356
34.35	14,346	14,055	12,599	15,098
34.65	13,182	12,980	12,713	14,706
35.03	11,605	11,685	11,076	12,496
35.40	11,756	13,023	12,653	13,799
35.71	11,724	11,572	10,600	11,772
36.02	11,210	10,831	10,060	11,222
36.32	9,944	9,925	9,301	10,915
36.70	12,352	12,738	12,482	13,741
37.00	11,484	12,054	11,775	12,638
37.38	11,744	11,613	11,097	12,565
37.67	14,194	13,791	13,364	14,658
37.98	14,201	14,672	14,246	15,430
38.44	15,033	15,414	14,393	15,741
38.66	13,151	13,199	12,452	14,086
39.04	13,010	12,913	12,507	13,785
39.34	11,343	11,403	12,440 4/	14,090 5/
39.57	11,082	10,903	12,260 4/	14,160 5/
39.87	13,331	13,250	11,503	13,438
40.02	13,229	13,664	11,813	13,549
40.25	12,756	13,581	11,636	13,569
40.48	13,293	14,050	11,859	13,744
40.63	37,133	39,487	32,673	36,987
40.85	16,291	16,291	16,291	16,291

1/ Below zero sounding line, which is 2.5 feet above COE datum at Golden Gate (1.1 feet below mean sea level).

2/ Average of double planimetered areas.

3/ No soundings were made in 1977 between River Miles 25-31, as maintenance dredging was limited to the area above RM 31.

4/ Settling Basin depth was authorized at 35-foot depth.

5/ Settling Basin depth is now authorized to 40-foot depth.

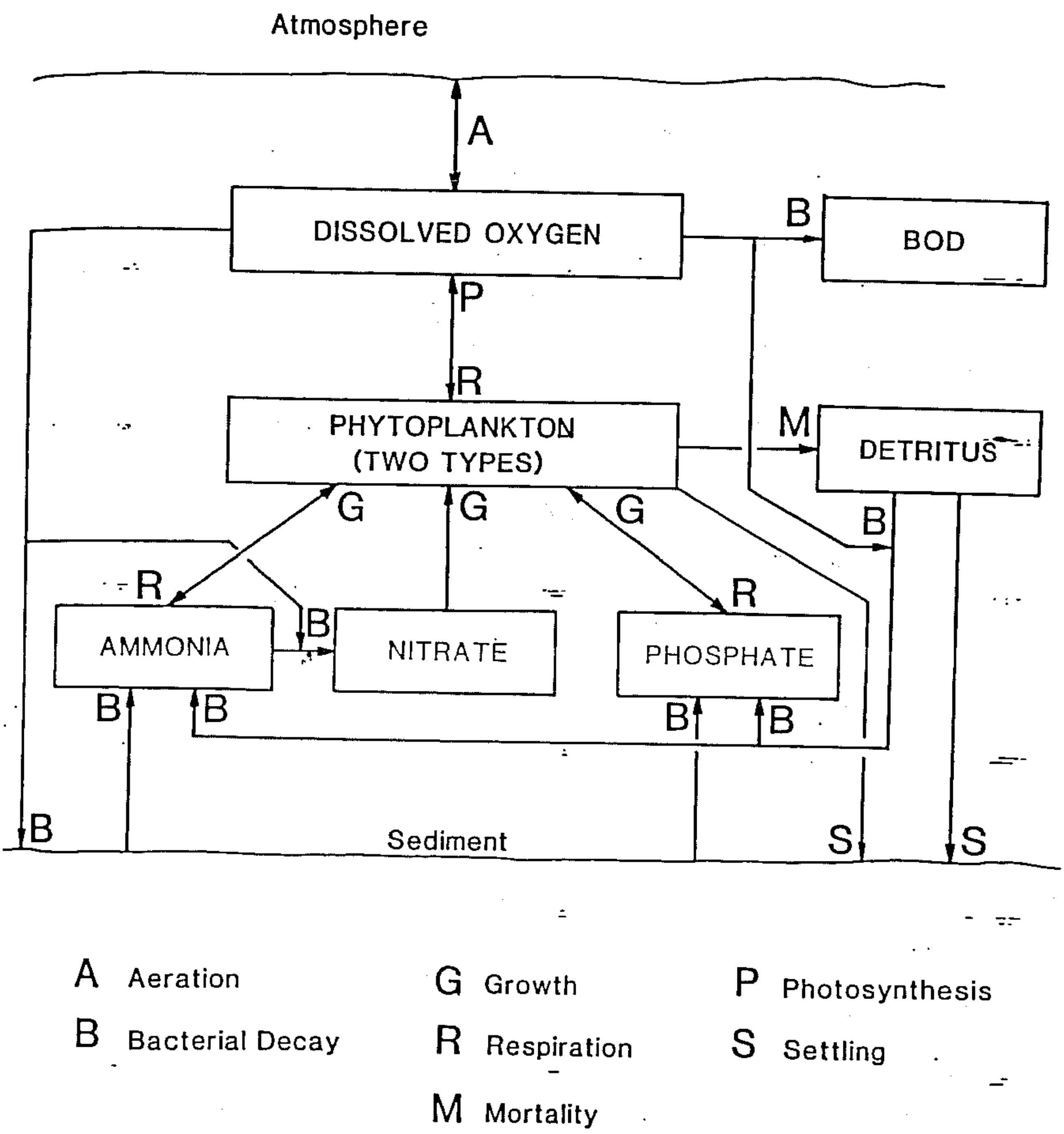


FIGURE III-3. INTERACTIONS AND COUPLING BETWEEN THE STOCKTON SHIP CHANNEL WATER QUALITY MODEL PARAMETERS

CHAPTER IV

MODEL CALIBRATION AND VALIDATION

IV.1 MODE OF OPERATION

The hydrodynamic model has two modes of operation. In the repetitive dynamic solution mode, the hydrodynamic model is run for two or more tidal cycles with the same boundary conditions (i.e., one tide and one set of hydrology) until a repeating solution is reached. This mode is used to provide a solution for an average set of conditions or for the initial solution for a time series solution. The time series mode is used to provide a dynamic history of Delta hydrodynamics over an extended time period. In this mode, each day is simulated only once using a tide and hydrology which is updated daily.

Unlike the hydrodynamic model the water quality program has only one mode of operation. The program accepts as input the hydrodynamic solution at hourly intervals and progresses through the simulation period. If the quality model is using a repeating hydrodynamic solution as input, the interface tape is rewound when the end is encountered and the hydrodynamic solution is reused. Other quality boundary conditions (i.e., inflow quality, exchange quality, benthic source/sink rates, etc.) may be updated at any daily intervals.

For the hydrodynamic calibration and validation effort, each period began with one repetitive hydrodynamic solution to provide a good starting point. The quality model was also run several days using the repetitive hydrodynamic solution to minimize effects of the initial conditions. Several days hydrodynamic/water quality simulation using the time series mode followed.

IV.2 HYDRODYNAMIC MODEL CALIBRATION

The calibration process involves adjusting one or more model parameters until adequate agreement between the simulation results and prototype measurements is achieved. In the San Francisco Bay Delta system, the most abundant data suitable for calibration is tidal stage. The model parameter adjusted during the calibration process was the Mannings roughness coefficient.

Model calibration was accomplished by simulating the entire calibration period followed by adjusting the Mannings roughness coefficients in selected channels to affect tidal magnitude and phasing. Model simulation followed by roughness coefficient adjustment was repeated until reasonable agreement was reached between the computed and observed tidal stage throughout the Delta with emphasis on the tidal stage data nearest the project area. The final roughness coefficients of the calibrated model were within the generally accepted range for slow moving natural and man-made channels and ranged from 0.025 for well maintained straight channels to 0.045 for the more natural meandering channels.

In addition to the tidal stage calibration, DWR's estimates for the San Joaquin - Old River flow split and the cross Delta channel flows were compared with computed values for the periods when these data were available. The San Joaquin River flow below Old River was based on a nomograph developed by the DWR which relates total San Joaquin River flow to State and Federal export rates. During the periods when the Old River barrier was in place, field observations were relied on for the flow estimates. The estimated Delta Cross Channel and Georgiana Slough flows are reported in the Day Flow Summary (3).

Calibration Period One

Model calibration was performed for two time periods. The first period, June 8 through June 12, 1978 was selected because the San Joaquin River inflow was relatively high and provided an opportunity to insure that the model adequately represented net flow through the Delta. In evaluating the water quality in the Stockton Ship Channel, net flow north through the Delta from the San Joaquin River is very important since it affects the flow residence time (i.e., the length of time the water has resided within the system), the flow volume and associated water quality entering the Stockton Ship Channel. The hydrology for this period is summarized in Table IV-1. To demonstrate the calibrated model, the computed stage and the observed tidal extremes have been plotted for the DWR tide stations shown in Figures IV-1 through IV-4. These plots show that both the magnitude and phasing of the tidal extremes are reproduced reasonably well. Simulation was made to be best at stations in the immediate vicinity of the Stockton Ship Channel (Figure IV-3).

Calibration Period Two

The second period, September 11 through September 25, 1974, was selected because it was typical of later summer conditions, and the Old River barrier was constructed. Water quality problems commonly occur in the Stockton Ship Channel during late summer low flows. During the second period, low oxygen levels were measured in the Stockton Ship Channel near Stockton. The hydrology for this calibration period is summarized in Table IV-2.

Construction of the barrier was started on September 12 and proceeded normally until September 18. At that time unexpected high flow (3700 cfs) in the San Joaquin River forced nearly complete closure of Old River to prevent loss of the structure due to erosion. On September 21 and 22 a notch was cut in the structure to obtain the desired diversion. During the closure construction, it was estimated that 85% of the total flow continued down the San Joaquin during the period of September 18 through September 20 and that 45% of the flow continued down the river after the notch was cut in the structure (8). The effects of the Old River barrier were simulated by varying the Mannings roughness coefficient of the channel connecting nodes 150 and 162. A series of simulations were performed using various Mannings roughness coefficients until reasonable agreement between the computed and estimated flow in the San Joaquin River was achieved.

The calibration simulations were performed with the Mannings coefficient shown on Table IV-3. The table also shows the estimated and computed flow in the San Joaquin River below Old River. Reasonable agreement between the computed and estimated San Joaquin River flow below Old River was reached for all days. The results of the tidal stage calibrations are shown in Figures IV-5 through IV-10. Figures IV-5 through IV-7 show the simulated and the observed stage at two hour intervals for six stations on the San Joaquin River and Stockton Ship Channel. Figures IV-8 through IV-10 show the same observed stages plotted against the corresponding computed value. Note that these points should fall on a forty-five degree line for perfect agreement. These figures show that the simulated stage magnitude and phasing matches the observed values at all six locations on the San Joaquin River and in the Stockton Ship Channel reasonably well.

IV.3 HYDRODYNAMIC MODEL VALIDATION

The model validation process includes simulation of a period not used for calibration and comparison of results with observed data. The model can be considered validated and ready for use as a predictive tool if the simulation compares favorably with observed data.

The September 26, 1978 through October 10, 1978 period was selected for model validation. During this period, the old river barrier was not in place, however, special operations were initiated in an attempt to alleviate low dissolved oxygen levels in the San Joaquin River below Stockton. During this period, the Delta pumps were turned off for 4 days and releases to the Mendota Pool increased in an attempt to force more water north in the San Joaquin River past the Old River bifurcation and raise dissolved oxygen levels. No attempt was made during this study to evaluate the success of this unusual operation. The hydrology for the validation period is summarized in Table IV-4.

The results from the tidal stage validation are shown in Figures IV-11 through IV-16. Figures IV-11 through IV-13 show the simulated stage and the observed stage at two hour intervals for five stations on the San Joaquin River and Stockton Ship Channel. Figures IV-14 through IV-16 show the same observed stages plotted against the corresponding computed value. A review of these figures shows that the model represents tidal stage very well at these gage locations.

In addition to the above stage comparisons, the computed net cross Delta channel and Georgiana Slough flow and San Joaquin River flow below Old River were compared with the flows estimated by the DWR (9). The computed and estimated flows are shown in Table IV-5. The computed and estimated net flows through the cross Delta channel are almost identical. The match between the computed and estimated flows in the San Joaquin River are not as close but are within acceptable limits.

The good agreement between the computed and observed stages at all locations indicates that the hydrodynamic model is adequately calibrated and ready for use in the evaluation of the effects of the Stockton Ship Channel dredging project.

IV.4 WATER QUALITY MODEL CALIBRATION

The water quality model was calibrated to dissolved oxygen measurements taken by the California DWR and the City of Stockton during the test periods. Sampling trips by the DWR were made starting near sunrise (8,9) to minimize the influence of photosynthesis on DO measurements. The sampling days were generally selected such that the low water slack tide condition occurred at the time the samples were collected. The date and time of the sampling cruises were selected in an attempt to measure the lowest level during the day. Dissolved oxygen was generally measured at 3 feet below the surface and 3 feet above the bottom.

Dissolved oxygen measurements are subject to variability from several sources. Although the first samples were taken early in the day, the last sample may have been collected much later in the day due to travel time constraints. The model was calibrated to simulate "average" DO quality. This "average" predicted value is similar to an accurate depth and width integrated sample taken simultaneously at each node. Depth-width integrated averages were approximated by comparison with the available data, described above.

The model relies on 31 physical, chemical and biological coefficients to simulate the responses and interactions of temperature and the 10 water quality parameters. Of these 31 coefficients, some are well defined by specific chemical relationships. Others are highly variable and are dependent on environmental conditions and specifics of the material represented by the parameter (i.e., types of phytoplankton represented by ALGAE1). Calibration was accomplished by a series of simulations in which one or more of the ill defined coefficients were adjusted until the simulated DO approximated the observed DO range. The coefficients for the calibrated model are shown in Table IV-6. The table includes a notation of the coefficients which were adjusted during the calibration process along with the normal range of values reported in the literature (4, 5, 6).

The inflow quality and tidal exchange quality for the calibration and validation period are summarized in Table IV-7. Meteorological data are input to the model at 3-hour intervals to account for diurnal variation. These data averaged for each day of simulation are summarized in Table IV-8.

Calibration Period

The period September 1 through September 26, 1974 was selected for water quality model calibration. During the calibration period, DO measurements were made by the DWR on September 6, 17 and 26, and by the City of Stockton on September 4, 18 and 26. Sampling locations for the test period are shown in Figure IV-17.

An examination of the DWR measurements shows that the minimum DO in the Stockton ship channel was about 4 mg/L on the 6th and declined to a low of about 1.5 mg/L on the 17th. The minimum DO then began to raise and was again at approximately 4.3 mg/L by the 26th. This rise can be attributed in part to increased net flows in the San Joaquin River resulting from the partial closure of Old River. The data collected by the City of Stockton indicates that the minimum DO was approximately 2.5 mg/L on September 4 and 2.0 mg/L on September 18.

The inflow quality of the San Joaquin River and other major tributaries was based on one or two measurements taken during the month of September. The Stockton waste water facility effluent was based on plant operation data. No attempt was made to vary the quality of any of these inflows during the calibration.

The calibrated model does not match extreme variations observed during the test period due in part to the use of average inflow conditions. Rather, the model was calibrated to approximate average conditions in the Stockton Ship Channel. Predicted low water slack tide DO profiles are plotted with observed near surface and bottom DO concentration in Figure IV-18. The observed minimum DO concentration on September 4, 6, 17 and 26 were 2.5, 4.0, 1.5 and 4.3 mg/L. Such variability of daily extremes is not unusual over a short test period due to constantly varying environmental conditions. No attempt was made to match the variable DO profile by varying the inflow quality since there were not sufficient measurement during the calibration period. Selection of variable inflow data would have resulted in a better fit of the observed DO; however, the inflow quality would have become a calibration parameter.

IV.5 WATER QUALITY MODEL VALIDATION

The calibrated model was validated using data from the September 26, 1978 to October 10, 1978 test period. During the validation period, DO measurements were made by the DWR on September 29 and October 3, 6 and 10, and by the City of Stockton on October 4 and 6. Both the DWR and the City measurements were made near low water slack. Near surface and bottom measurements were made where variations in concentration over the water column existed except for the October 6 city measurement which was near surface only.

The average inflow and exchange quality were estimated from available data and the model was run for the 15 day period without varying any model parameters. Low water slack tide predicted DO profiles are plotted with observed near surface and bottom concentrations in Figure IV-19. The calibrated model matches observed DO ranges well on October 2, 6 and 10 of the validation period. The match between the predicted and observed DO profile is not as good on September 29, however, this date is only 3 days from the beginning of the simulation and the initial conditions are likely affecting the results. Predicted daily extremes are plotted with DWR measurements of the near surface and bottom concentrations in Figure IV-20. The computed range in concentration during the day is not directly comparable to the range over the water column. Therefore, this figure is only intended to give an indication of the range in concentration due to diurnal effects and DO stratification. This figure can be used to relate the computed diurnal range to the average DO levels presented in the various oxygen plots keeping in mind that this variation is due to both the variation in photosynthetic activity and the tidal excursion of the DO sag.

In the turning basin, oxygen was sharply stratified during the validation period with near surface DO levels above saturation and near bottom levels as low as 2 mg/L. The sharp stratification is caused by flow velocities too low to force vertical mixing and high levels of photosynthetic activity coupled with a high oxygen demand throughout the water column. The simulated vertically mixed DO concentration during this period ranged from 4 to 5 mg/L.

Additional water quality parameters simulated by the model were not calibrated due to insufficient data. However, predicted concentrations for nitrate-nitrogen, phosphate-phosphorous, total coliform, detritus, ultimate carbonaceous BOD, ammonia-nitrogen, diatoma, and other algal species were within the ranges typically observed during September and October in the Stockton Ship Channel.

TABLE IV-1

DELTA HYDROLOGY FOR THE PERIOD OF
JUNE 8 THROUGH JUNE 12, 1978

	INFLOWS, cfs			WITHDRAWALS, cfs			
DATE	San Joaquin River	Consumnus and Mokelumne River	Sacramento River	Tracy Pumping	Delta Pumping	Contra Costa Pumping	CHANNEL DEPLETIONS, cfs
June 8	9500	866	13700	3540	2124	111	3400
June 9	8950	869	12400	3930	2046	115	3450
June 10	8470	821	12200	3920	3087	115	3500
June 11	8250	809	12300	3910	3864	112	3550
June 12	7990	813	12400	3890	4910	110	3600

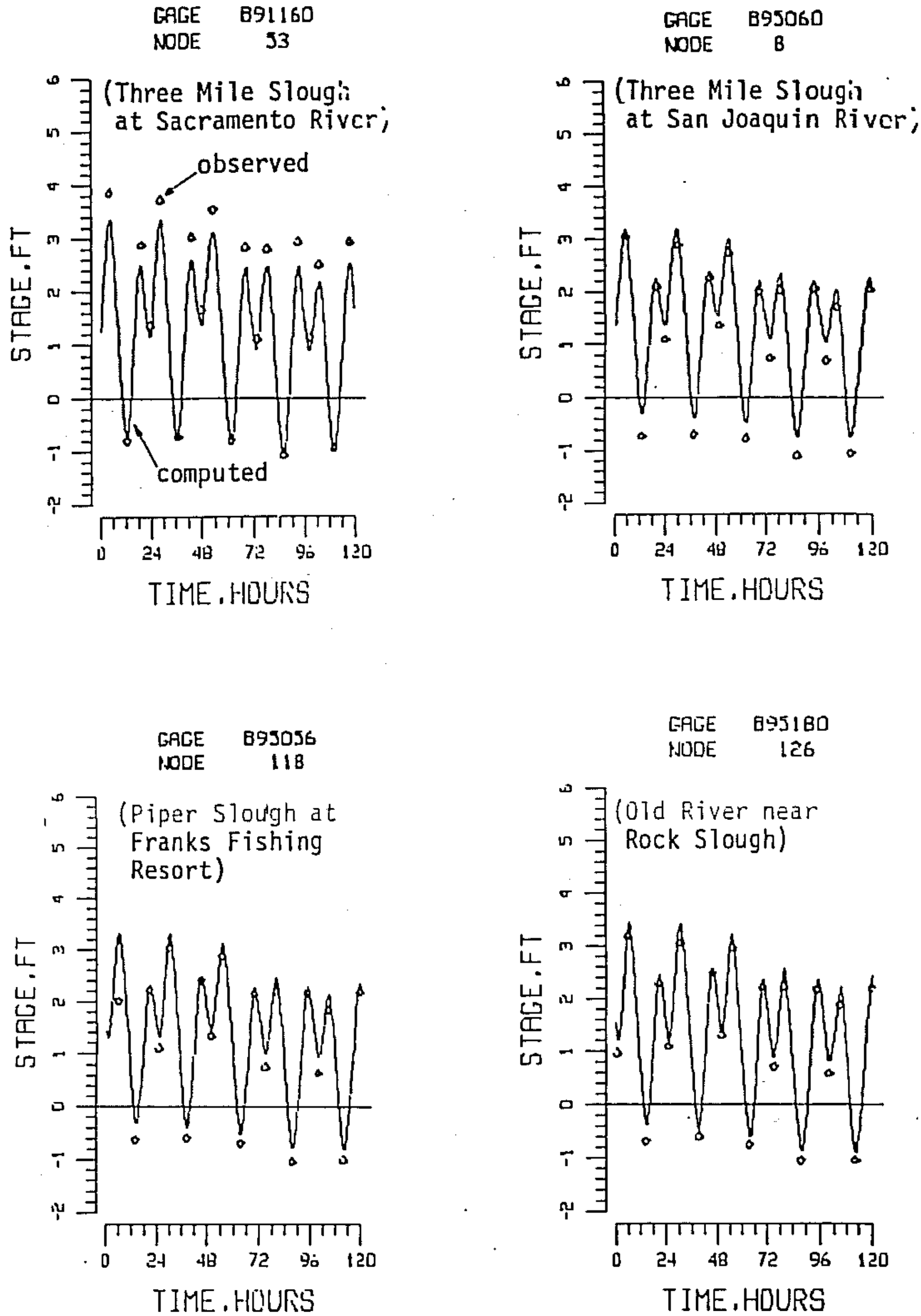


FIGURE IV-1

COMPUTED AND OBSERVED TIDAL STAGE AT
DWR TIDE GAGES B91160, B95060, B95056 AND B95180 FOR
THE JUNE 8 THROUGH JUNE 12, 1978 CALIBRATION PERIOD

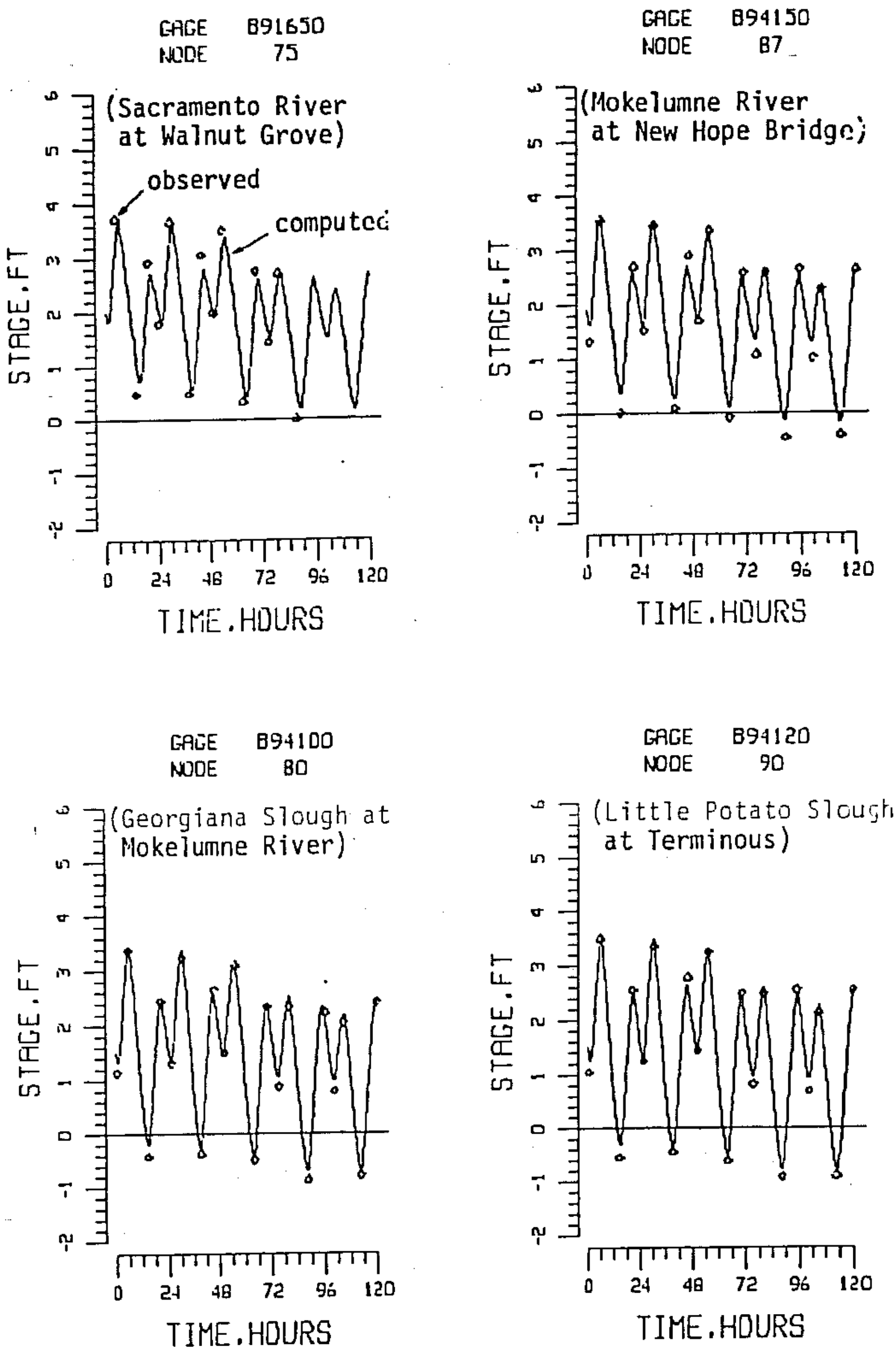


FIGURE IV-2

COMPUTED AND OBSERVED TIDAL STAGE AT
DWR TIDE GAGES B91650, B94150, B94100 AND B94120 FOR
THE JUNE 8 THROUGH JUNE 12, 1978 CALIBRATION PERIOD

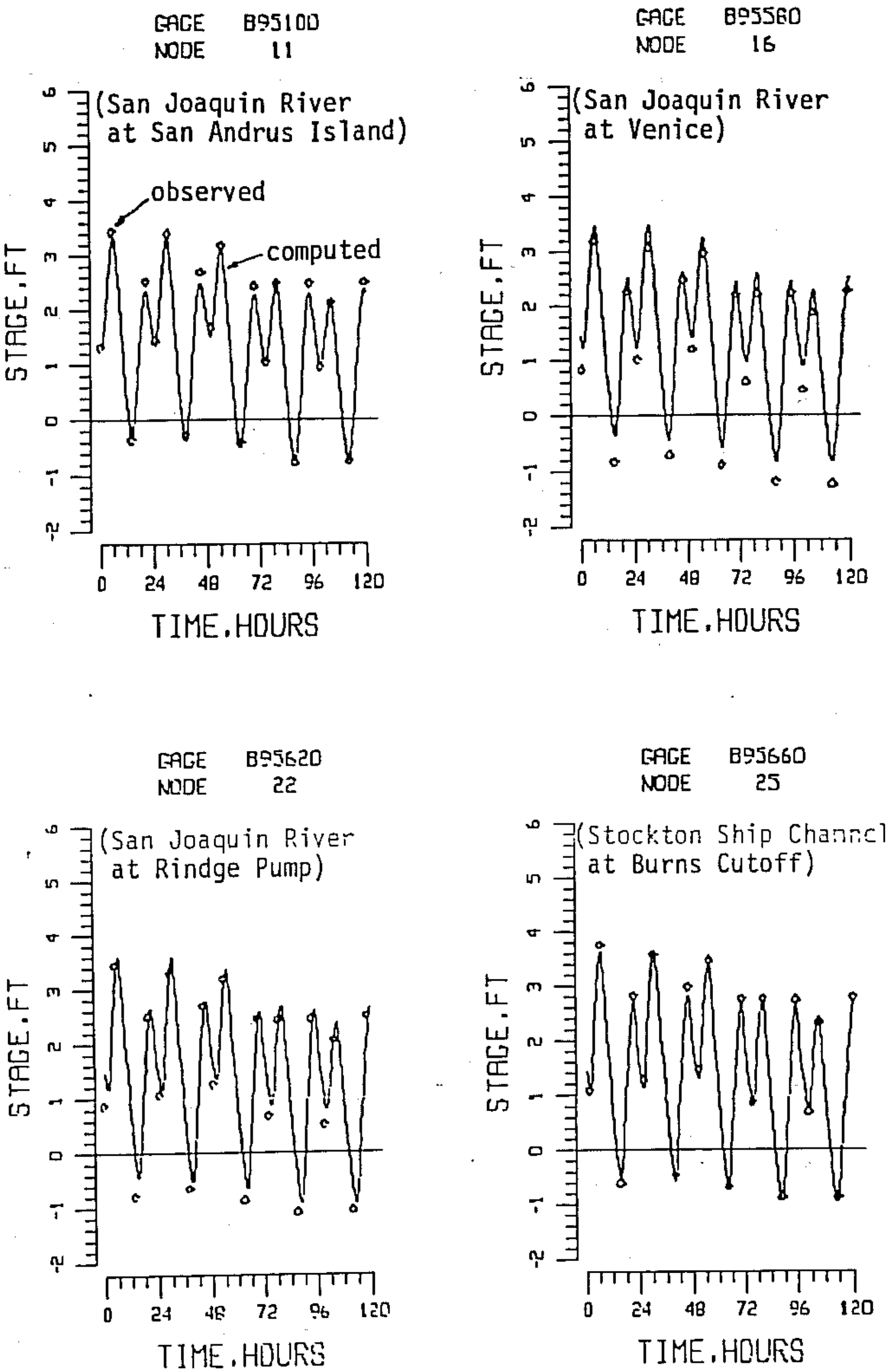


FIGURE IV-3

COMPUTED AND OBSERVED TIDAL STAGE AT
DWR TIDE GAGES B95100, B95580, B95620 AND B95660 FOR
THE JUNE 8 THROUGH JUNE 12, 1978 CALIBRATION PERIOD

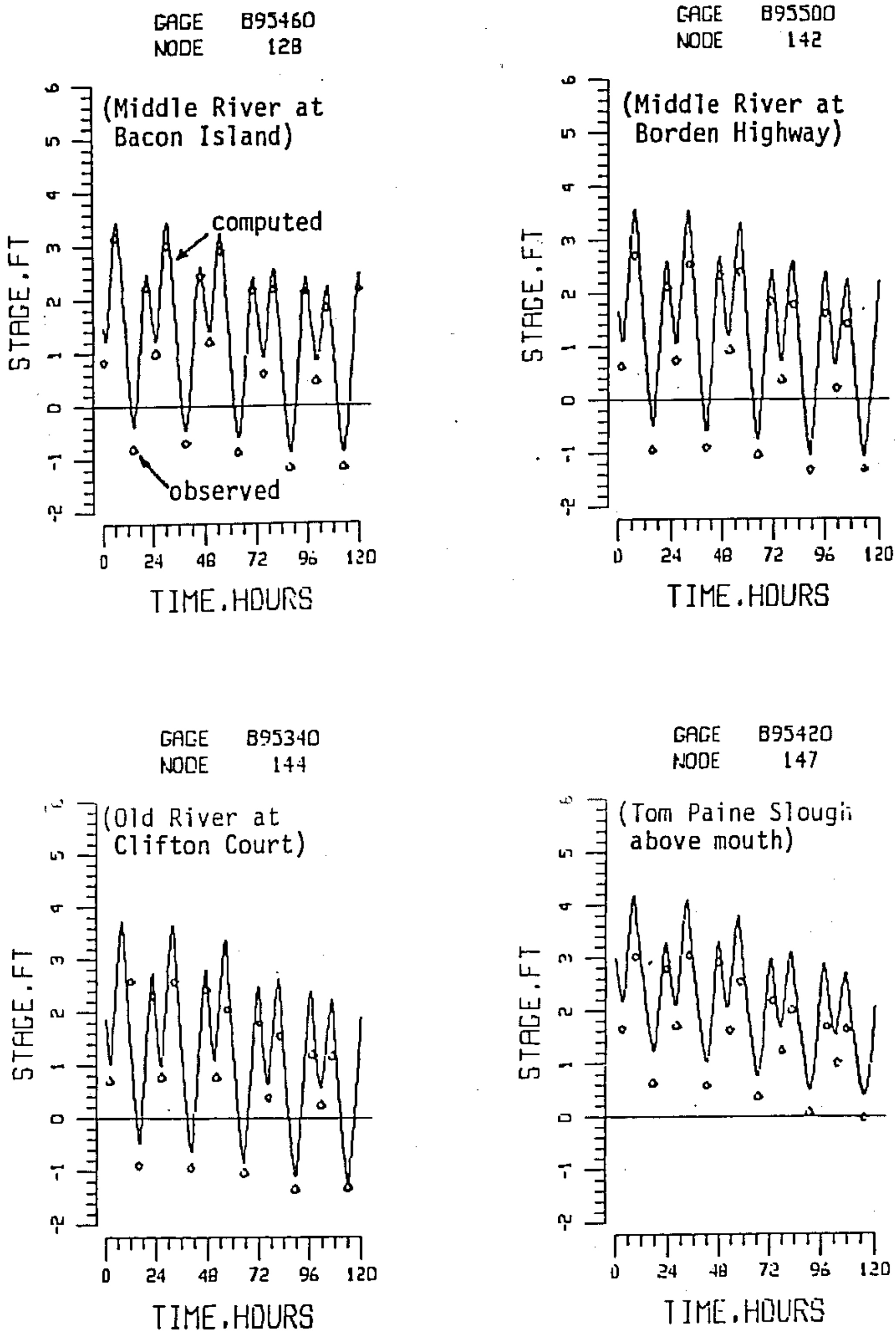


FIGURE IV-4

COMPUTED AND OBSERVED TIDAL STAGE AT
DWR TIDE GAGES B95460, B95500, B95340 AND B95420 FOR
THE JUNE 8 THROUGH JUNE 12, 1978 CALIBRATION PERIOD

TABLE IV-2

DELTA HYDROLOGY FOR THE SEPTEMBER 11 THROUGH SEPTEMBER 25, 1974 CALIBRATION PERIOD

DATE	INFLOWS, cfs			WITHDRAWALS, cfs			CHANNEL DEPLETIONS, cfs
	San Joaquin River	Consumnus and Mokelumne River	Sacramento River	Tracy Pumping	Delta Pumping	Contra Costa Pumping	
Sep 11	2390	527	27600	2860	5195	116	2800
Sep 12	2560	532	27600	2850	2895	127	2750
Sep 13	2500	590	27200	2860	1805	126	2700
Sep 14	2450	608	27000	2870	1489	123	2650
Sep 15	2420	614	26600	2770	1801	121	2600
Sep 16	2400	628	26500	2770	2517	122	2600
Sep 17	2420	599	26500	3260	1935	112	2550
Sep 18	2680	604	26500	3270	1364	107	2500
Sep 19	3150	605	26000	3330	1145	98	2450
Sep 20	3500	644	25200	3290	873	96	2450
Sep 21	3630	554	24200	3300	1194	95	2400
Sep 22	3620	546	23400	3290	3434	94	2350
Sep 23	3650	551	22900	3280	1098	94	2350
Sep 24	3480	540	22600	3260	768	93	2300
Sep 25	3520	544	22800	3300	1095	91	2250

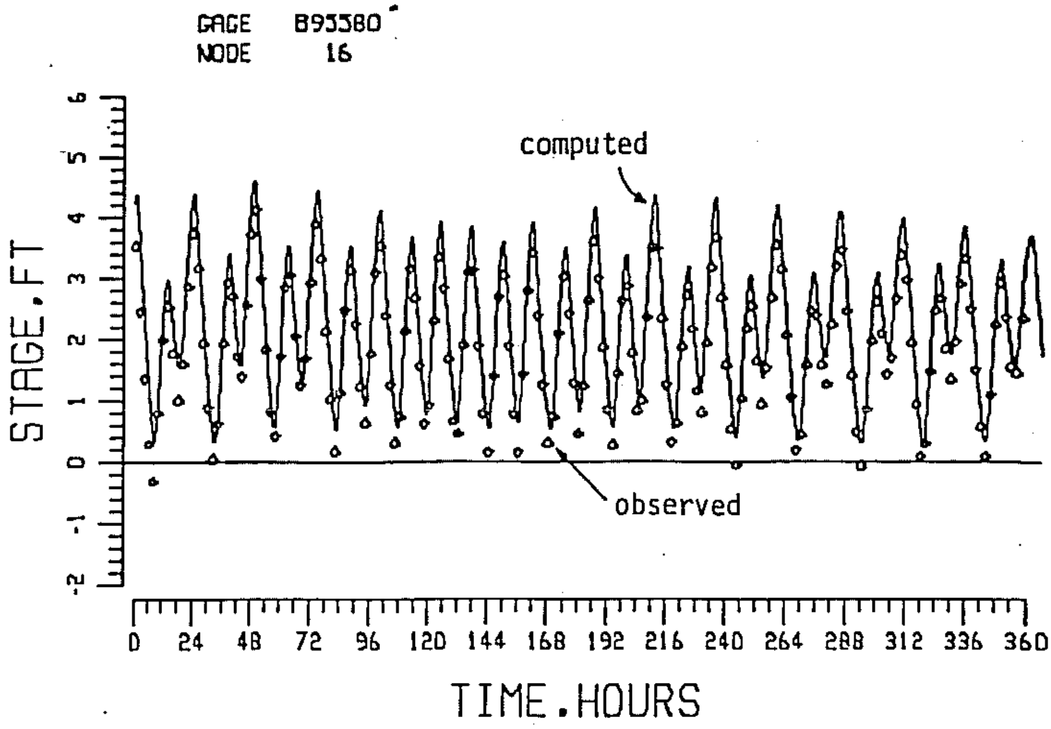
TABLE IV-3

EFFECTS OF THE OLD RIVER BARRIER
ON SAN JOAQUIN RIVER FLOWS FOR THE SEPTEMBER 11 THROUGH
SEPTEMBER 25, 1974 CALIBRATION PERIOD

DATE	SAN JOAQUIN RIVER	SAN JOAQUIN RIVER FLOW BELOW OLD RIVER		MANNINGS "n" NODE 162 TO 150	COMPUTED OLD RIVER FLOW**
		Estimated*	Computed**		
Sep 11	2390	400	330	0.030	1880
Sep 12	2560	250	621	0.040	1780
Sep 13	2500	500	800	0.055	1550
Sep 14	2450	1000	828	0.065	1400
Sep 15	2420	1050	890	0.070	1320
Sep 16	2400	1050	900	0.075	1290
Sep 17	2420	1700	1360	0.150	790
Sep 18	2680	2100	1870	0.250	540
Sep 19	3150	2500	2450	0.350	440
Sep 20	3500	2900	2810	0.350	480
Sep 21	3630	2400	2510	0.150	1010
Sep 22	3620	1900	2070	0.090	1460
Sep 23	3650	1600	1750	0.060	1830
Sep 24	3480	1550	1670	0.060	1770
Sep 25	3520	1500	1660	0.060	1780

* Flow rates estimated by individuals involved in the construction supervision of the Old River Barrier (8).

**Flows represent the average during the 24 hour period and are affected slightly by different tidal stages at the beginning of the day.



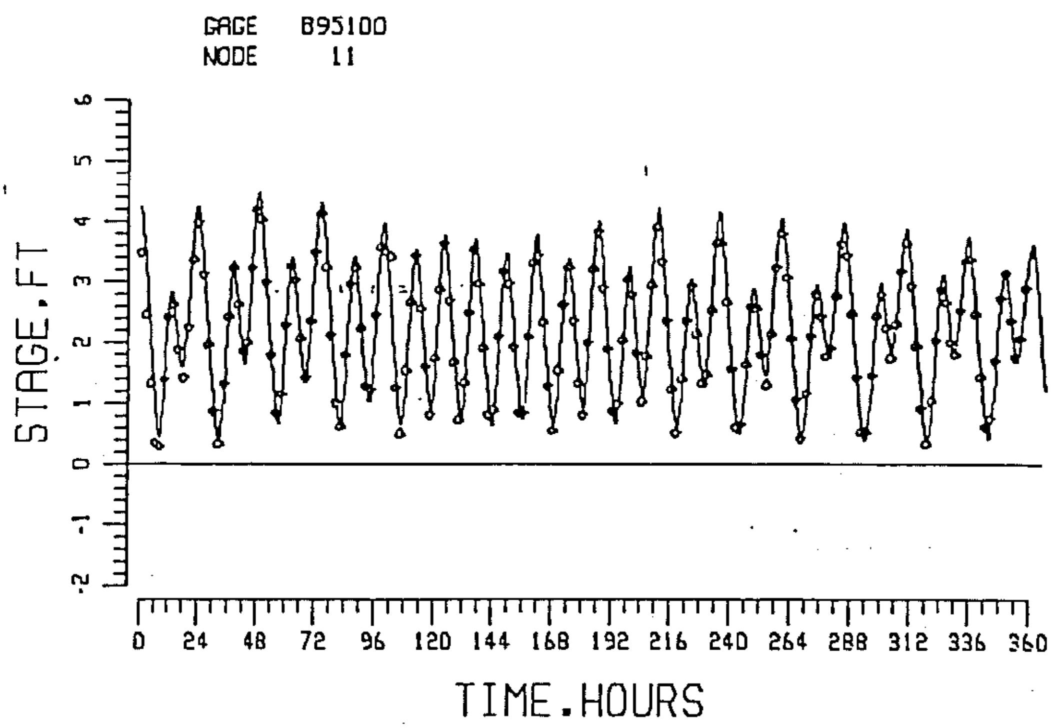
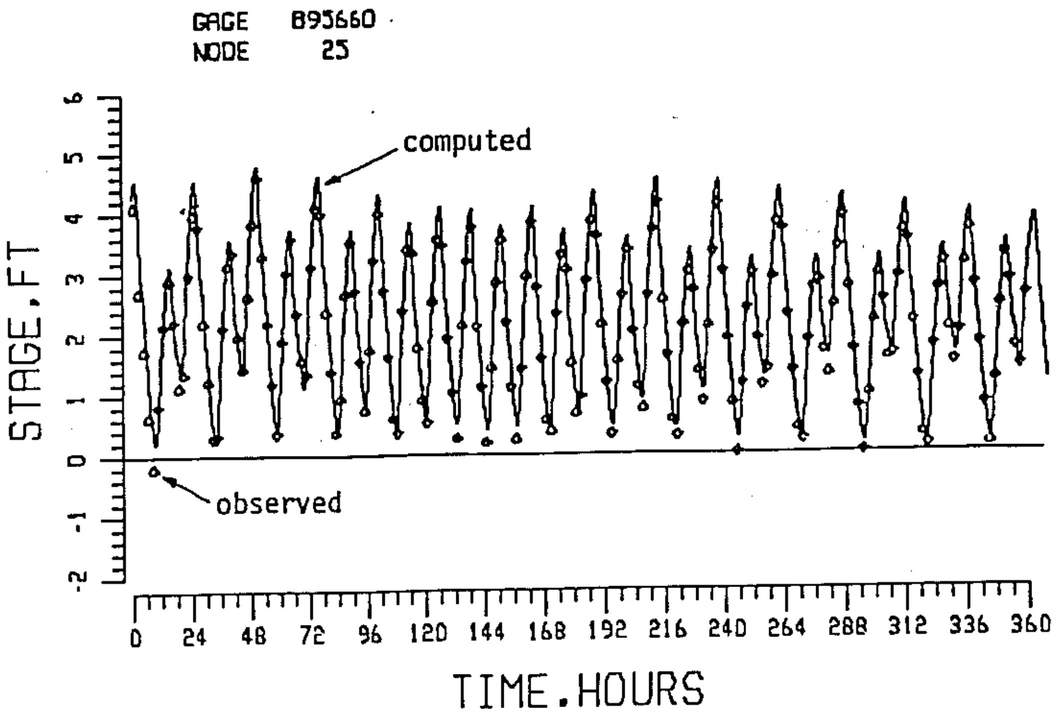


FIGURE IV-5

COMPUTED AND OBSERVED TIDAL STAGE ON THE
SAN JOAQUIN RIVER AT VENICE AND SAN ANDRUS ISLANDS FOR
THE SEPTEMBER 11 THROUGH SEPTEMBER 25, 1974 CALIBRATION PERIOD



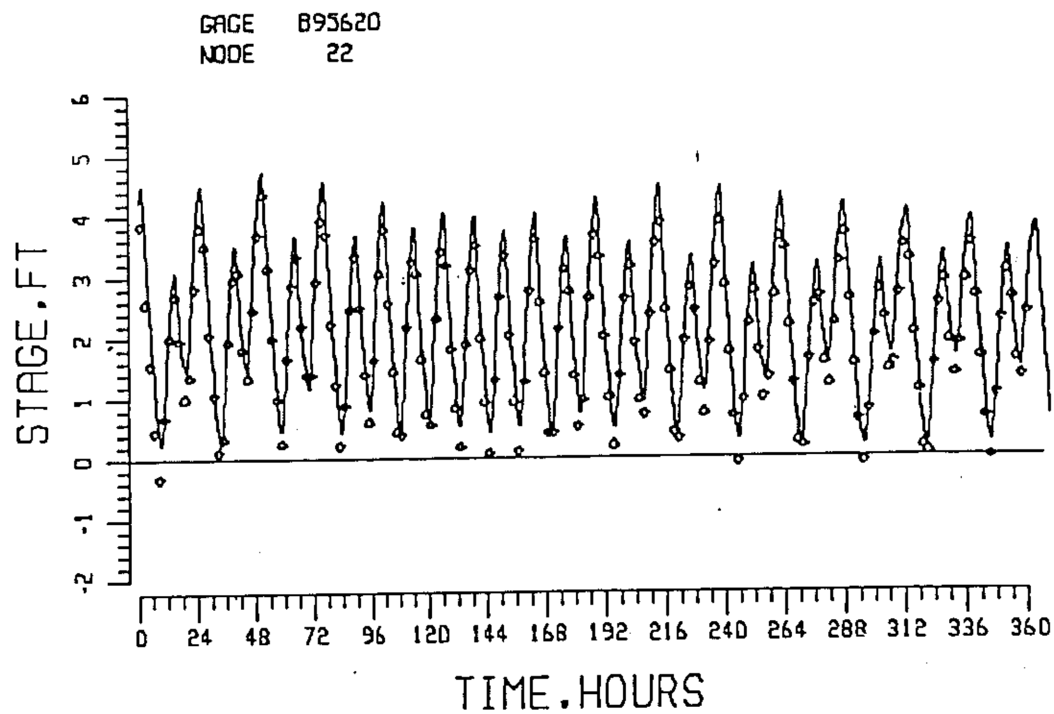
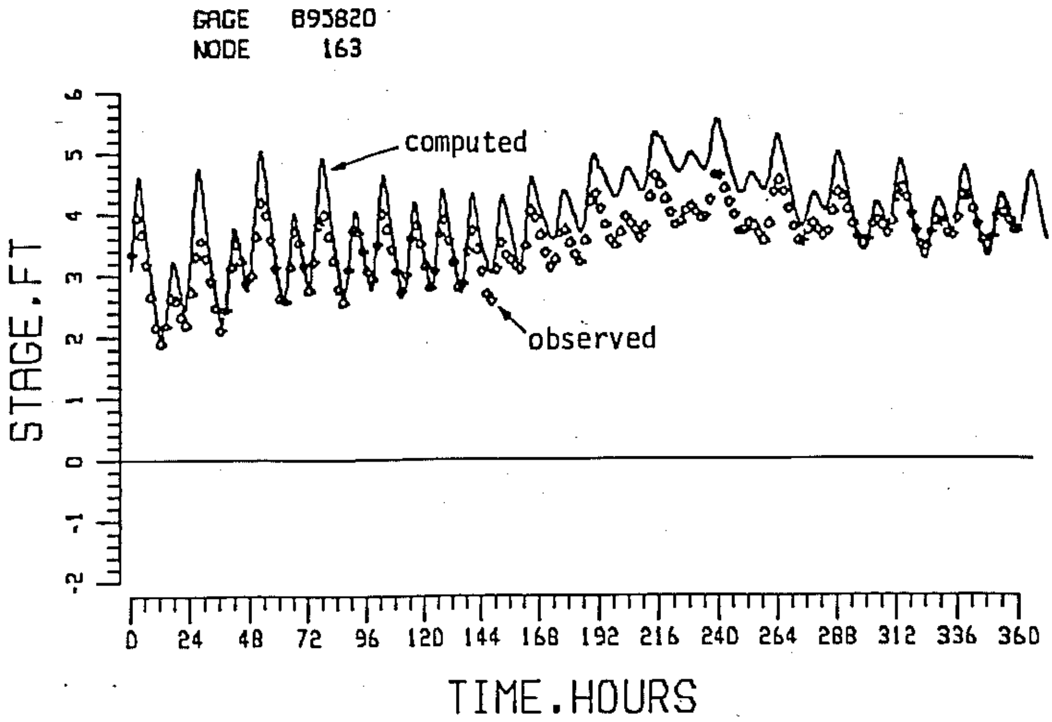


FIGURE IV-6

COMPUTED AND OBSERVED TIDAL STAGE ON THE
SAN JOAQUIN RIVER AT BURNS CUTOFF AND RINDGE PUMP FOR
THE SEPTEMBER 11 THROUGH SEPTEMBER 25, 1974 CALIBRATION PERIOD



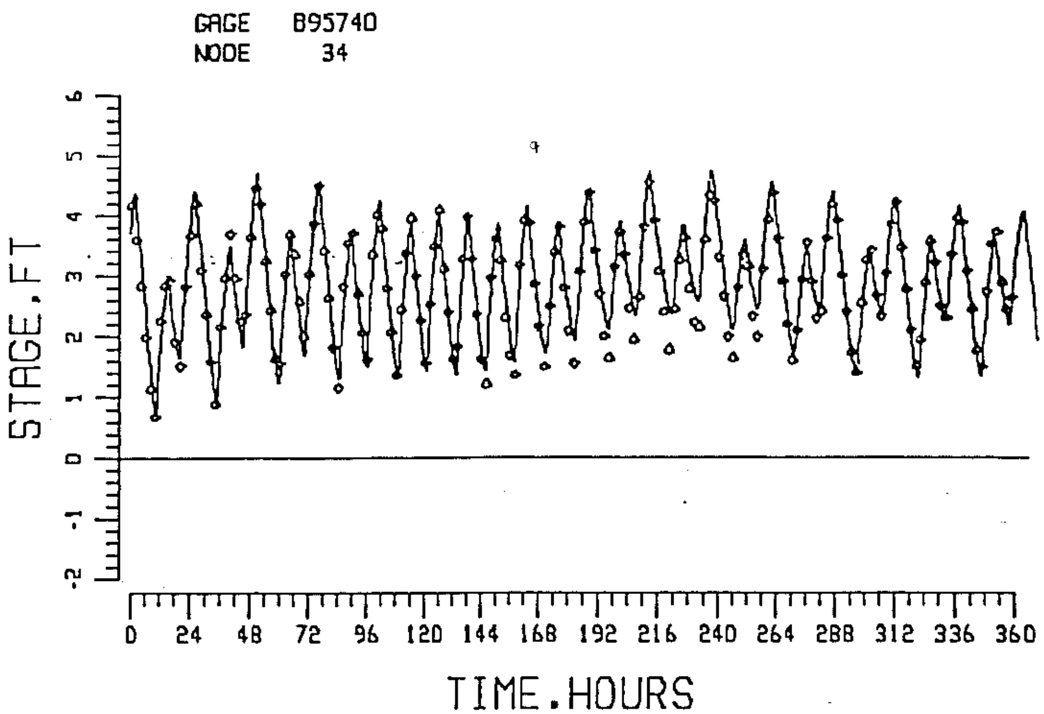


FIGURE IV-7

COMPUTED AND OBSERVED TIDAL STAGE ON THE
SAN JOAQUIN RIVER AT MOSSDALE AND BRANDT BRIDGES FOR
THE SEPTEMBER 11 THROUGH SEPTEMBER 25, 1974 CALIBRATION PERIOD

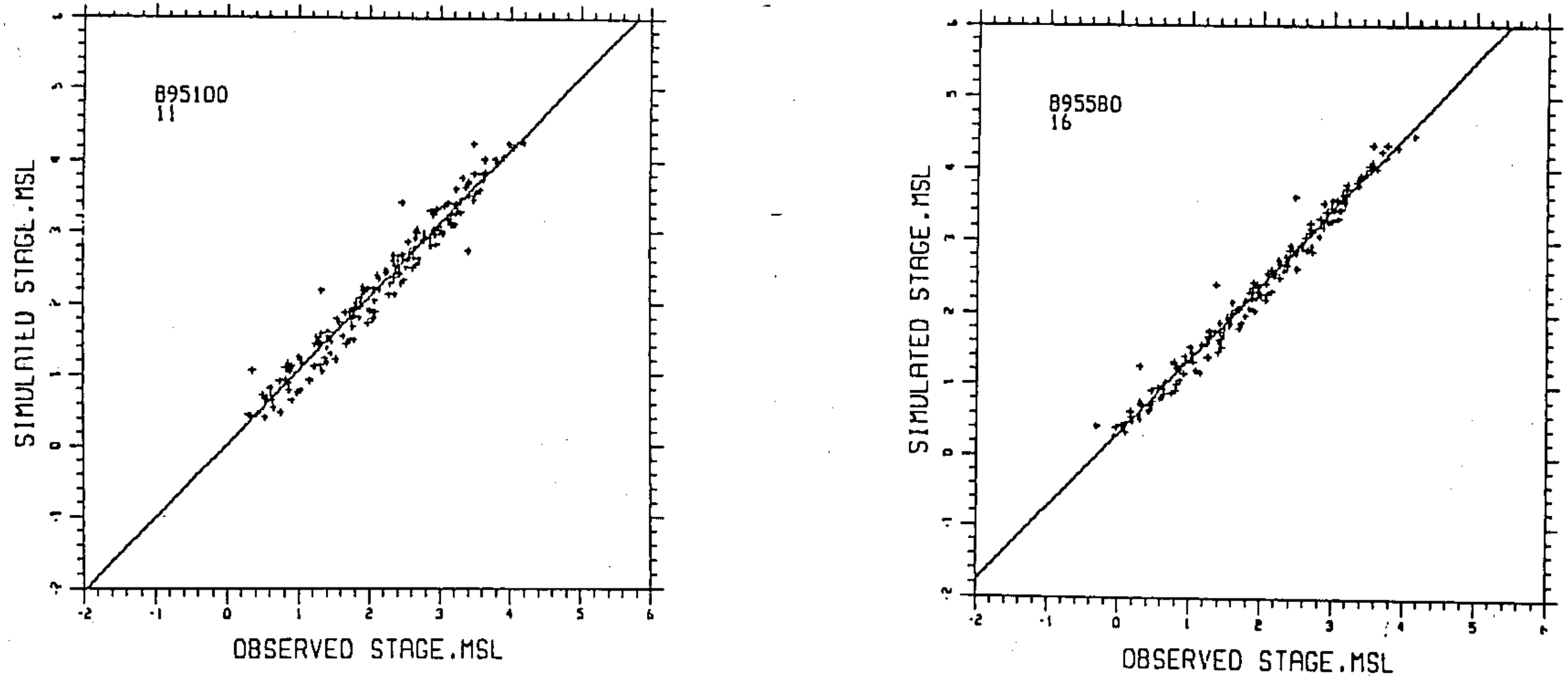


FIGURE IV-8

RELATIONSHIP BETWEEN THE COMPUTED AND OBSERVED TIDAL STAGE ON THE SAN JOAQUIN RIVER AT SAN ANDRUS AND VENICE ISLANDS FOR THE SEPTEMBER 11 THROUGH SEPTEMBER 25, 1974 CALIBRATION PERIOD

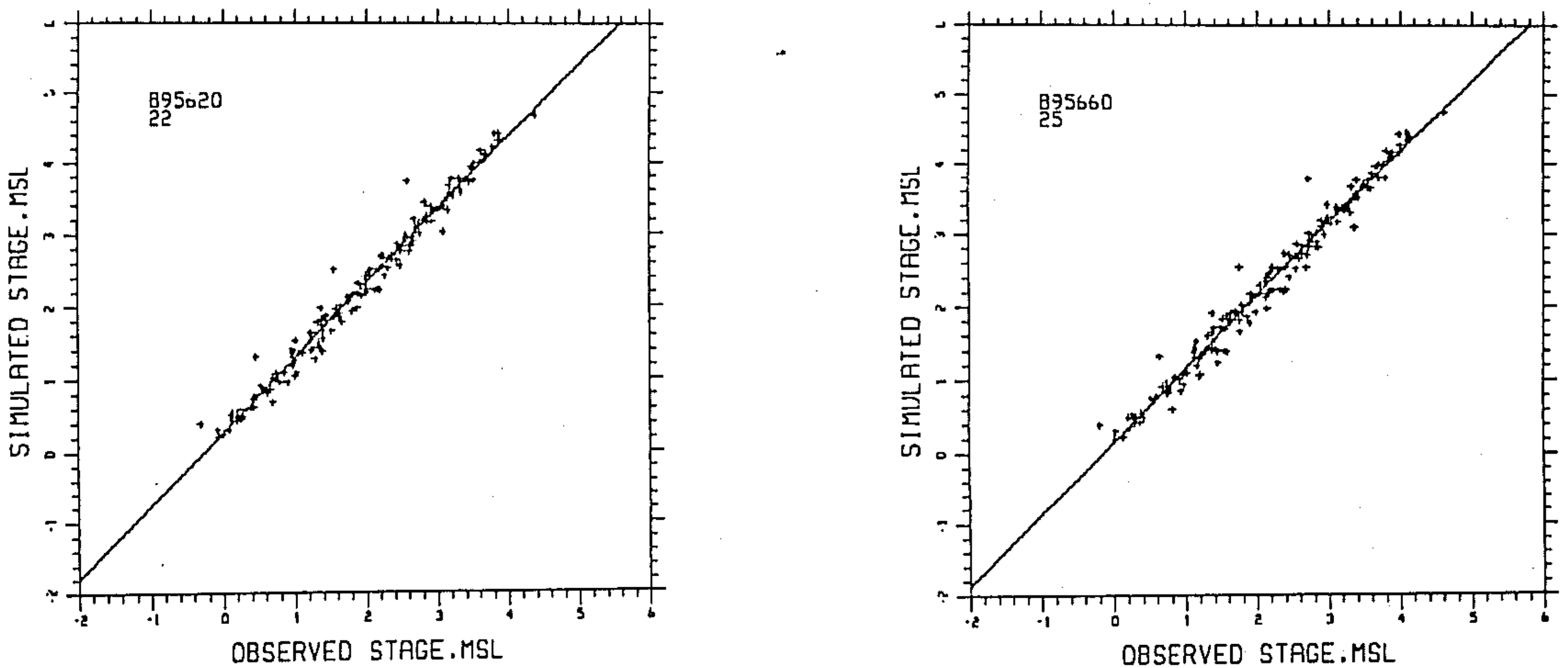


FIGURE IV-9

RELATIONSHIP BETWEEN THE COMPUTED AND OBSERVED TIDAL STAGE ON THE SAN JOAQUIN RIVER AT RINDGE PUMP AND THE STOCKTON SHIP CHANNEL AT BURNS CUTOFF FOR THE SEPTEMBER 11 THROUGH SEPTEMBER 25, 1974 CALIBRATION PERIOD

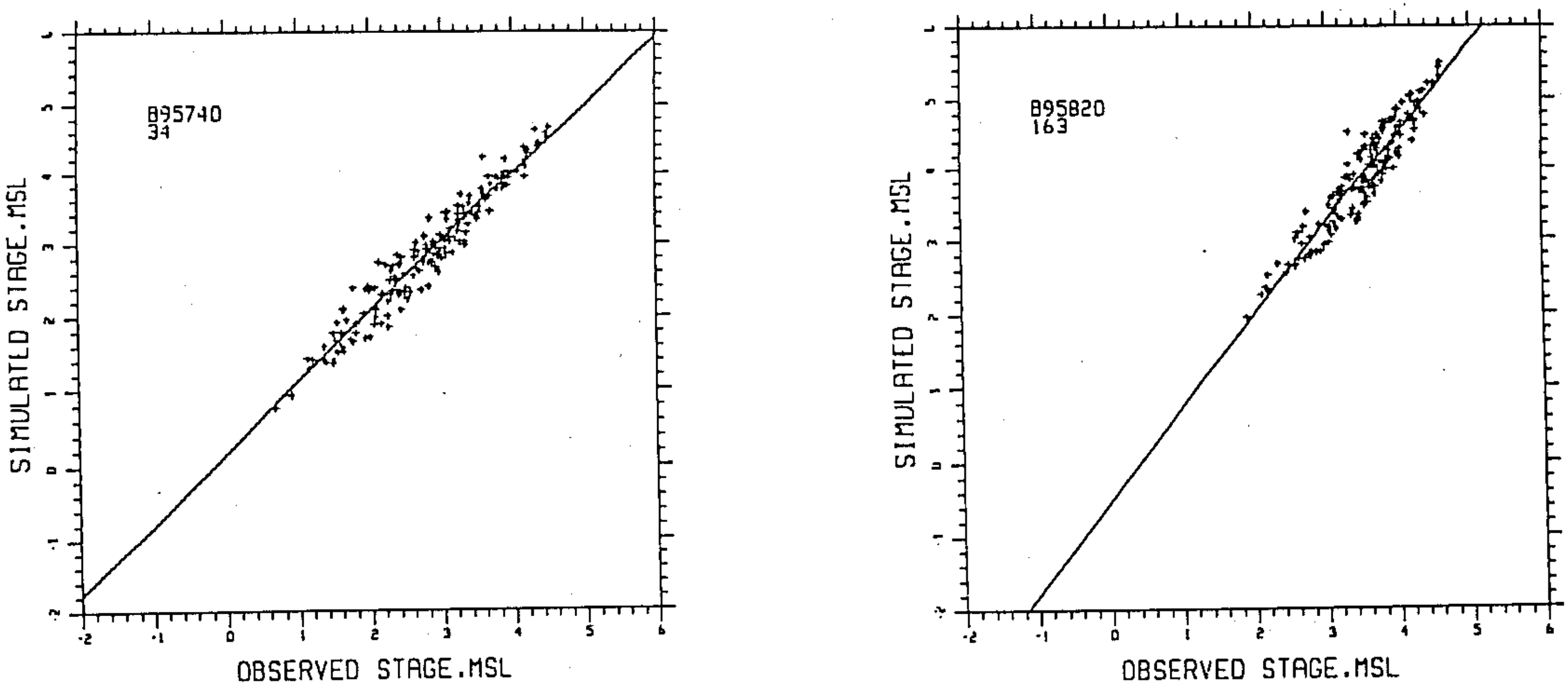


FIGURE IV-10

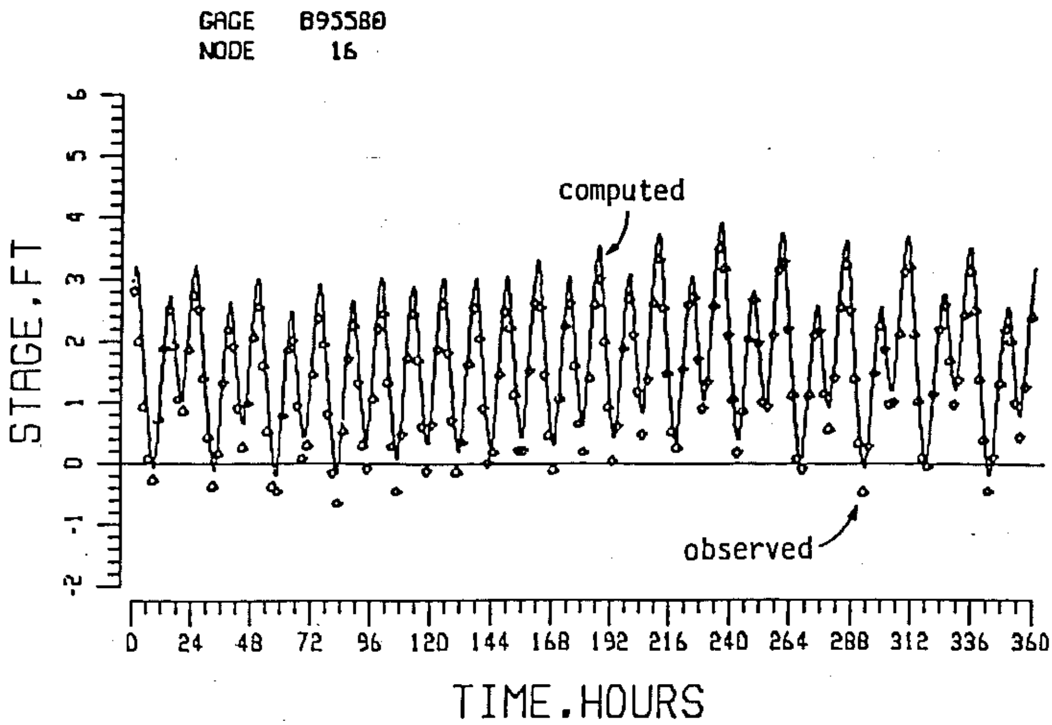
RELATIONSHIP BETWEEN THE COMPUTED AND OBSERVED
TIDAL STAGE ON THE SAN JOAQUIN RIVER AT BRANDT AND MOSSDALE BRIDGES FOR
THE SEPTEMBER 11 THROUGH SEPTEMBER 25, 1974 CALIBRATION PERIOD

TABLE IV-4

DELTA HYDROLOGY FOR THE SEPTEMBER 26 THROUGH OCTOBER 10, 1978 VALIDATION PERIOD

DATE	INFLOWS, cfs			WITHDRAWALS, cfs			CHANNEL DEPLETIONS, cfs
	San Joaquin River	Consumnus and Mokelumne River	Sacramento River	Tracy Pumping	Delta Pumping	Contra Costa Pumping	
Sep 26	3000	886	16300	3200	1660	122	2250
Sep 27	2970	899	16200	3190	1264	121	2200
Sep 28	3060	904	16000	3180	2126	122	2200
Sep 29	3030	924	15800	3180	2057	131	2150
Sep 30	2080	921	15900	3190	2706	130	2150
Oct 1	3180	927	15700	3187	3094	136	2150
Oct 2	3180	943	15500	1153	-44*	135	2100
Oct 3	3200	869	15300	821	-49*	129	2050
Oct 4	4120	842	14500	820	-39*	133	2050
Oct 5	3580	842	14200	1022	-50*	131	2000
Oct 6	3240	841	14200	3246	2944	131	2000
Oct 7	3210	779	14200	3249	3022	114	1950
Oct 8	3240	751	14000	3269	3012	110	1950
Oct 9	3230	747	14300	3246	3008	113	1950
Oct 10	3100	729	13600	3266	1123	108	1900

* Negative withdrawals result from zero pumping and a decrease in the Clifton Court water surface elevation.



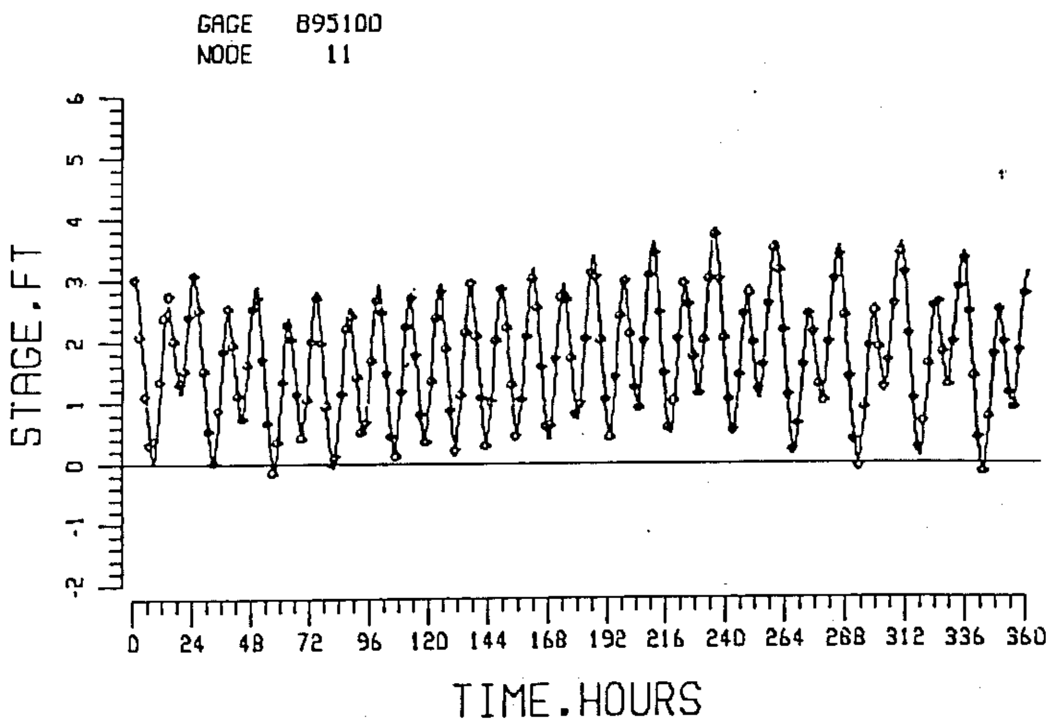
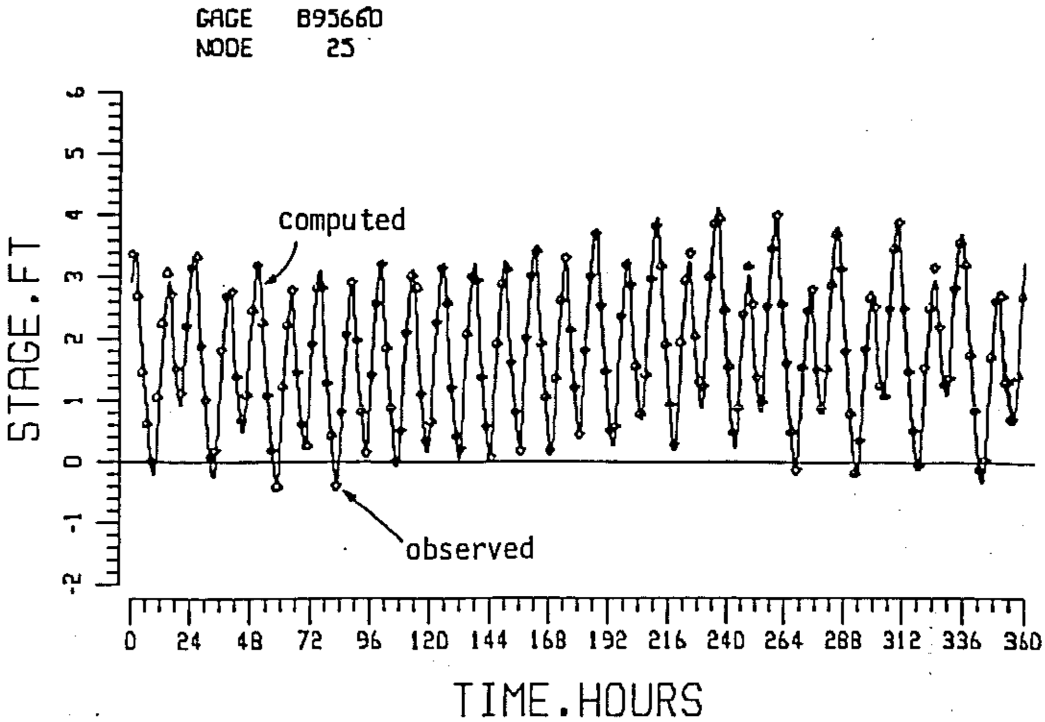


FIGURE IV-11

COMPUTED AND OBSERVED TIDAL STAGE ON THE SAN JOAQUIN RIVER
AT VENICE AND SAN ANDRUS ISLANDS FOR
THE SEPTEMBER 26 THROUGH OCTOBER 10, 1978 VALIDATION PERIOD



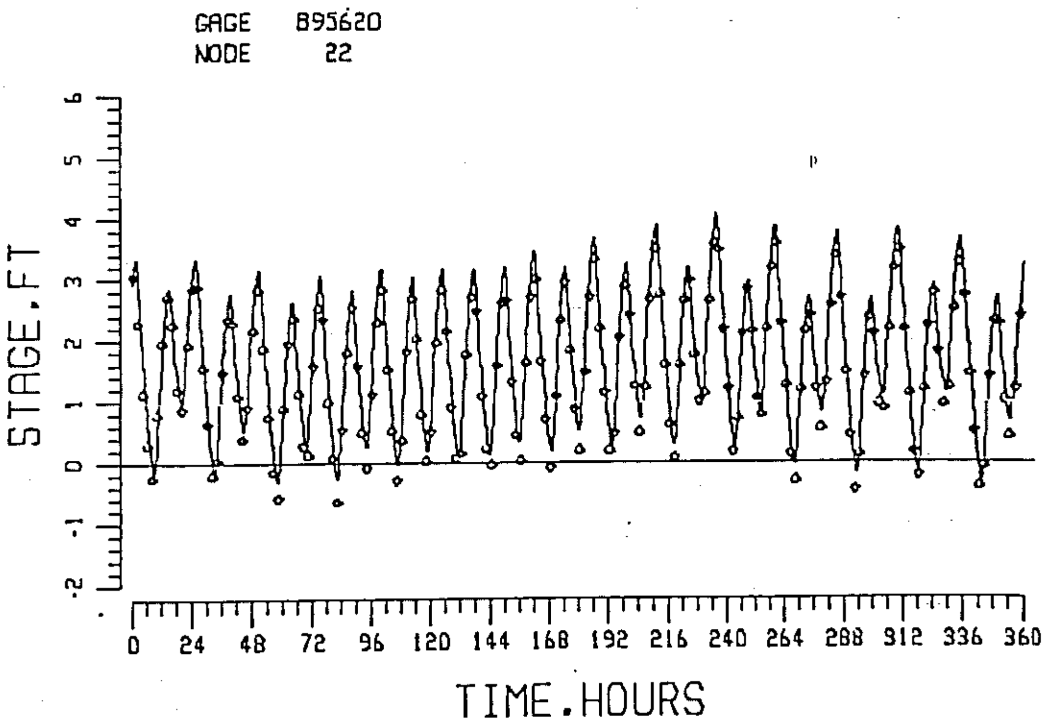


FIGURE IV-12

COMPUTED AND OBSERVED TIDAL STAGE ON
THE SAN JOAQUIN RIVER AT BURNS CUTOFF AND AT RINDGE PUMP
FOR THE SEPTEMBER 26 THROUGH OCTOBER 10, 1978 VALIDATION PERIOD

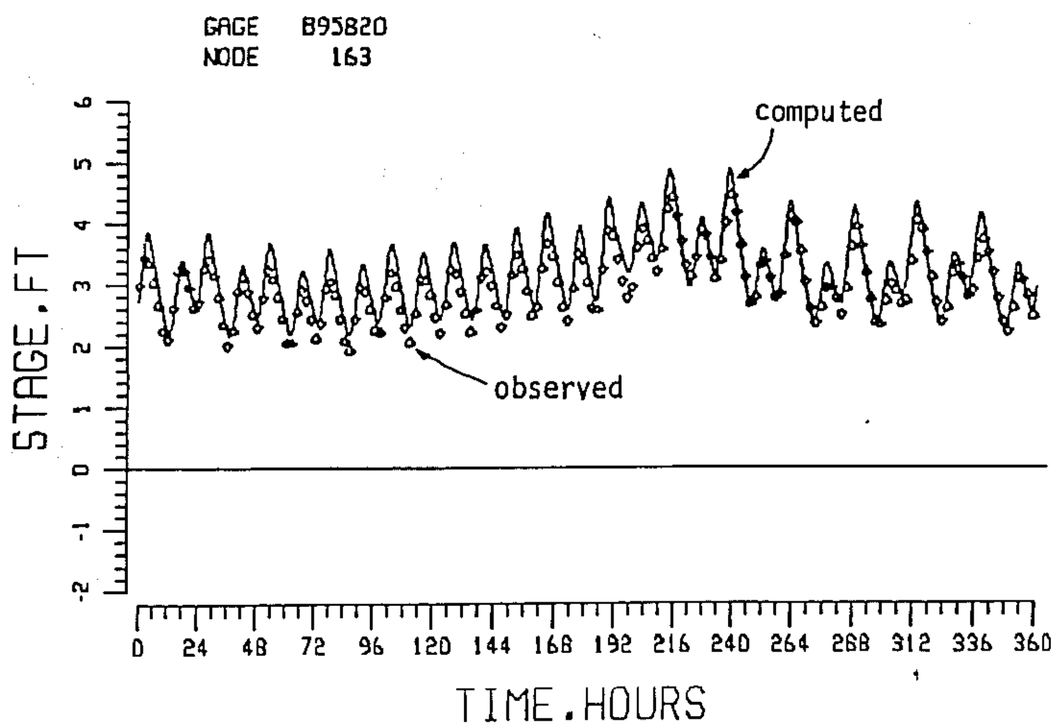


FIGURE IV-13

COMPUTED AND OBSERVED TIDAL STAGE ON
THE SAN JOAQUIN RIVER AT MOSSDALE BRIDGE FOR
THE SEPTEMBER 26 THROUGH OCTOBER 10, 1978 VALIDATION PERIOD

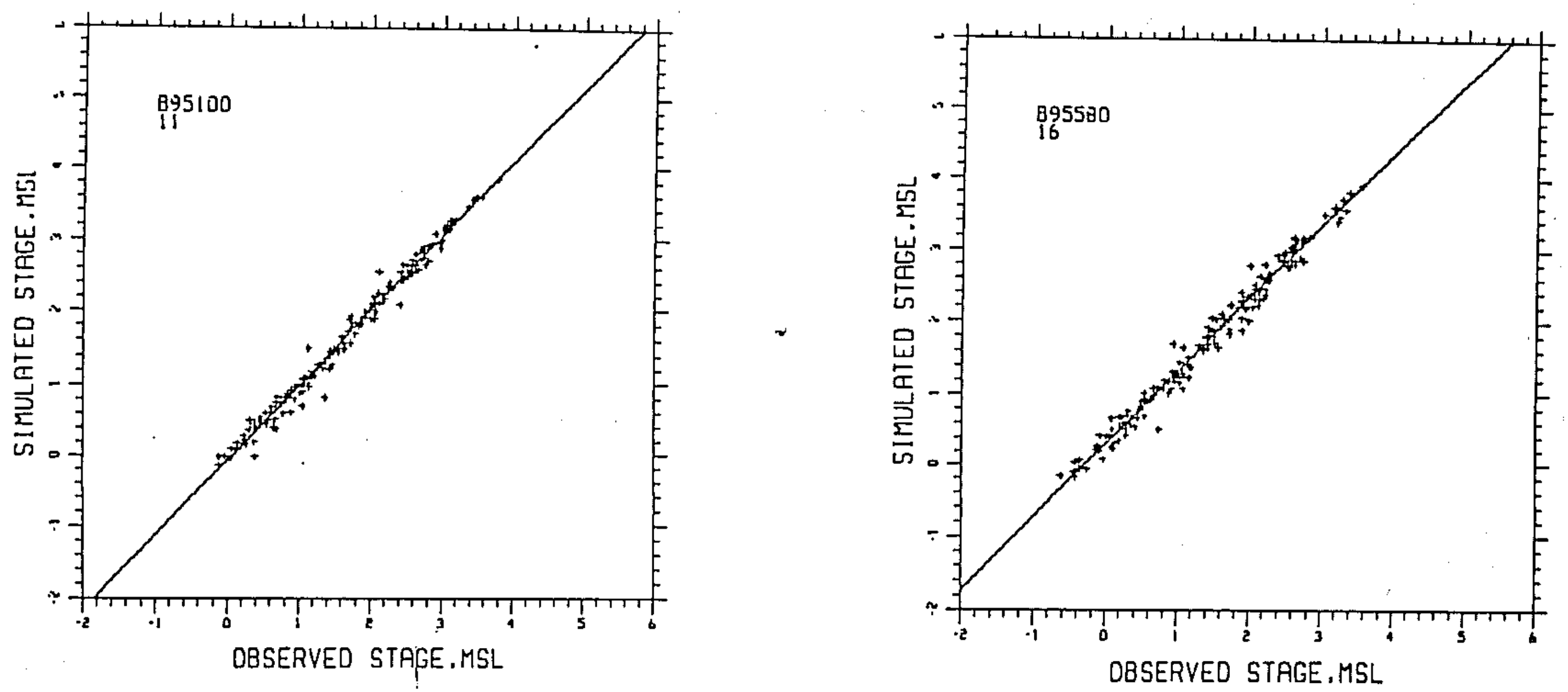


FIGURE IV-14

RELATIONSHIP BETWEEN THE COMPUTED AND OBSERVED TIDAL STAGE ON THE SAN JOAQUIN RIVER AT SAN ANDRUS AND VENICE ISLANDS FOR THE SEPTEMBER 26 THROUGH OCTOBER 10, 1978 VALIDATION PERIOD

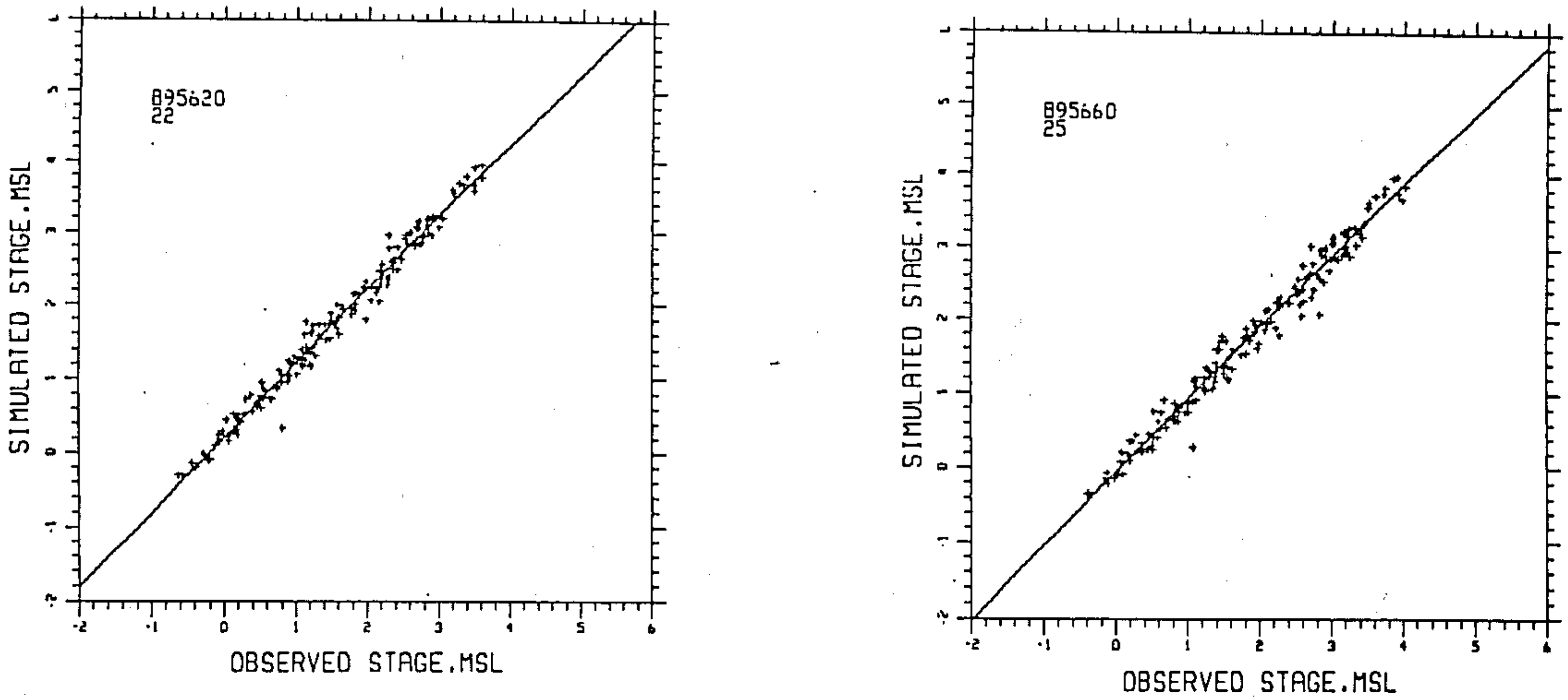


FIGURE IV-15

RELATIONSHIP BETWEEN THE COMPUTED AND OBSERVED TIDAL STAGE ON THE SAN JOAQUIN RIVER AT RINDGE PUMP AND THE STOCKTON SHIP CHANNEL AT BURNS CUTOFF FOR THE SEPTEMBER 26 THROUGH OCTOBER 10, 1978 VALIDATION PERIOD

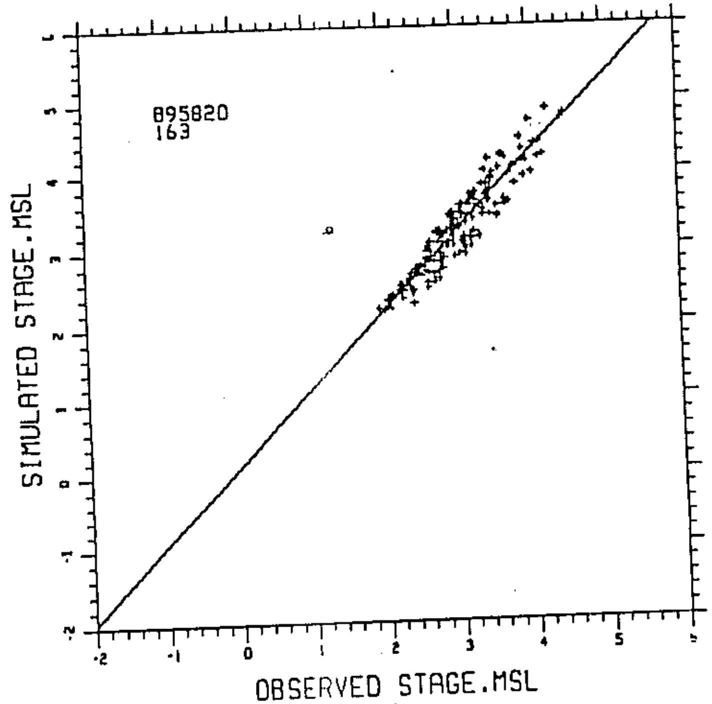


FIGURE IV-16

RELATIONSHIP BETWEEN THE COMPUTED AND OBSERVED TIDAL STAGE ON THE SAN JOAQUIN RIVER AT MOSSDALE BRIDGE FOR THE SEPTEMBER 26 THROUGH OCTOBER 10, 1978 VALIDATION PERIOD

TABLE IV-5

COMPUTED AND ESTIMATED FLOWS IN THE SAN JOAQUIN RIVER AND DELTA CROSS CHANNEL AND GEORGIANA SLOUGH DURING THE SEPTEMBER 26 THROUGH OCTOBER 10, 1978 VALIDATION PERIOD

	SAN JOAQUIN RIVER BELOW OLD RIVER		DELTA CROSS CHANNEL AND GEORGIANA SLOUGH	
DATE	Estimated*	Computed	Estimated**	Computed
Sep 26	--	540	6886	6784
Sep 27	--	687	6837	6675
Sep 28	476	634	6778	6696
Sep 29	443	568	6719	6715
Sep 30	446	518	6749	6787
Oct 1	434	507	6690	6778
Oct 2	939	665	6632	6622
Oct 3	981	715	6573	6590
Oct 4	1526	1075	6339	6316
Oct 5	1303	891	6251	6198
Oct 6	460	615	6251	6301
Oct 7	435	522	6251	6329
Oct 8	435	507	6192	6255
Oct 9	437	609	6280	6392
Oct 10	611	797	6075	6218

* Estimated by the DWR (9). Based on DWR nomograph made from 25-hour tidal cycle measurements.

**Estimates provided by the DWR in the Day Flow Summary (3).

TABLE IV-6

CHEMICAL, PHYSICAL AND BIOLOGICAL COEFFICIENTS

COEFFICIENT	TYPICAL RANGE (4,5,6)	CALIBRATED VALUE
Nitrogen fraction of phytoplankton	.02-.09	0.080
Phosphorus fraction of phytoplankton	.005-.012	0.012
Nitrogen fraction of detritus	.02-.09	0.080
Phosphorus fraction of detritus	.002-.012	0.012
Settling rate for Algae 1, M/day	0-2	0.500*
Settling rate for Algae 2, M/day	0-1	0.150*
Detritus settling rate, M/day	0-2	0.250*
BOD decay rate, 1/day	.1-.3	0.200*
Detritus decay rate, 1/day	.001-.05	0.040*
Ammonia decay rate, 1/day	.04-.2	0.100*
Coliform die off rate, 1/day	.5-3.	1.000
Temperature adjustment for BOD decay	1.03-1.06	1.047
Temperature adjustment for ammonia decay	1.02-1.03	1.022
Temperature adjustment for coliform die off	1.03-1.06	1.040
Temperature adjustment for detritus decay	1.02-1.04	1.025
Ratio of oxygen uptake to ammonia decay	4.6	4.600
Ratio of oxygen uptake to detritus decay	1.2-2.0	1.600
Ratio of oxygen production to phytoplankton photosynthesis	1.6	1.600
Ratio of oxygen uptake to phytoplankton respiration	1.6	1.600
Light extinction coefficient for detritus, 1/M-mg/ℓ	.01-.25	0.200
Light extinction coefficient for phytoplankton, 1/M-mg/ℓ	.15-.25	0.200
Maximum growth rate for Algae 1, 1/day	1.-3.	2.000*
Maximum growth rate for Algae 2, 1/day	1.-4.	2.500*
Respiration rate for Algae 1, 1/day	.05-.3	0.200*
Respiration rate for Algae 2, 1/day	.05-.3	0.250*
Light half saturation for Algae 1 growth, kcal/m^2/sec	.002-.004	0.002*
Light half saturation for Algae 2 growth, kcal/m^2/sec	.003-.006	0.006*
Nitrogen half saturation for Algae 1 growth, mg/ℓ	.03-.10	0.050
Nitrogen half saturation for Algae 2 growth, mg/ℓ	.05-.20	0.200
Phosphorus half saturation for Algae 1 growth, mg/ℓ	.02-.05	0.020
Phosphorus half saturation for Algae 2 growth, mg/ℓ	.03-.06	0.050

* Values selected during the calibration process

TABLE IV-7. QUALITY OF THE TIDAL EXCHANGE AND MAJOR INFLOWS FOR THE QUALITY MODEL CALIBRATION AND VALIDATION PERIOD (MOST OF THESE VALUES ARE DETERMINED FROM ONE OR TWO MEASUREMENTS DURING THE PERIOD)

Node	TDS (mg/L)	NO_3-N (mg/L)	PO_4-P (mg/L)	Coliforms (MPN/100 ml)	BOD (mg/L)	Detritus (mg/L)	NH_3-N (mg/L)	DO (mg/L)	Temp (°C)	Algae 1 (mg/L)	Algae 2 (mg/L)
CALIBRATION PERIOD (SEPTEMBER 11-26, 1974)											
Tidal Exchange - Antioch											
1	1000	.045	.04	500	.6	2.0	.03	8.8	21	1.50	.10
Mokelumne River											
89	50	.110	.05	500	.1	1.0	.05	8.3	20	.22	.02
Sacramento River											
65	80	.090	.05	500	.1	1.0	.10	8.3	20	.21	.01
San Joaquin River											
163	800	.750	.08	1000	1.6	5.5	.03	7.7	22	4.50	.50
Stockton Regional Wastewater Treatment Plant											
158	1000	.350	7.00	100	15.0	23.0	4.00	8.0	24	1.00	25.00
VALIDATION PERIOD (SEPTEMBER 26 - OCTOBER 10, 1978)											
Tidal Exchange - Antioch											
1	1000	.020	.08	500	.3	2.0	.05	8.0	21	.35	.05
Mokelumne River											
89	50	.150	.08	500	.3	1.0	.10	7.9	20	.35	.03
Sacramento River											
65	80	.100	.08	500	.2	1.0	.10	8.4	20	.27	.01
San Joaquin River											
163	800	.750	.15	1000	1.5	5.5	.10	8.5	20	2.70	.30
Stockton Regional Wastewater Treatment Plant											
158	1000	.350	7.00	100	25.0	13.0	2.00	6.0	22	2.00	40.00

TABLE IV-8. DAILY AVERAGE METEOROLOGICAL CONDITIONS FOR THE QUALITY MODEL CALIBRATION AND VALIDATION PERIODS (AVERAGE OF 3 HOUR OBSERVATION AT STOCKTON WSO)

Date	Cloud Cover (fraction)	Dry Bulb Temp (°C)	Wet Bulb Temp (°C)	Wind Speed (m/sec)	Atmospheric Pressure (mb)
Calibration Period					
Sep 1, 1974	0.04	23.5	12.7	3.4	1010
Sep 2, 1974	0.00	23.9	11.7	3.7	1011
Sep 3, 1974	0.00	23.0	10.7	4.2	1011
Sep 4, 1974	0.00	24.7	12.5	3.3	1010
Sep 5, 1974	0.00	26.8	12.7	2.9	1010
Sep 6, 1974	0.00	28.5	12.2	3.4	1012
Sep 7, 1974	0.00	27.6	11.3	3.7	1013
Sep 8, 1974	0.00	24.4	10.5	4.0	1012
Sep 9, 1974	0.00	25.2	12.1	3.8	1011
Sep 10, 1974	0.00	26.9	14.1	2.6	1009
Sep 11, 1974	0.00	26.1	9.7	4.4	1007
Sep 12, 1974	0.00	23.7	11.1	4.5	1009
Sep 13, 1974	0.00	20.7	11.7	4.2	1011
Sep 14, 1974	0.00	20.7	12.8	3.6	1014
Sep 15, 1974	0.00	22.2	12.2	3.4	1017
Sep 16, 1974	0.00	22.2	11.9	3.1	1016
Sep 17, 1974	0.00	24.0	11.8	3.0	1013
Sep 18, 1974	0.00	23.8	11.5	2.8	1012
Sep 19, 1974	0.00	22.1	11.6	3.6	1013
Sep 20, 1974	0.00	23.2	10.7	3.2	1013
Sep 21, 1974	0.00	23.6	11.0	3.1	1010
Sep 22, 1974	0.00	22.2	12.0	3.5	1007
Sep 23, 1974	0.00	22.0	11.5	3.3	1006
Sep 24, 1974	0.15	23.9	11.3	3.0	1009
Sep 25, 1974	0.45	20.0	10.9	4.0	1014
Sep 26, 1974	0.04	18.9	11.6	3.4	1013
Validation Period					
Sep 26, 1978	0.71	22.0	11.3	4.7	1015
Sep 27, 1978	0.29	21.4	11.6	3.5	1017
Sep 28, 1978	0.19	22.9	10.1	2.8	1016
Sep 29, 1978	0.00	24.2	10.8	1.7	1014
Sep 30, 1978	0.02	25.7	11.6	1.8	1015
Oct 1, 1978	0.00	25.0	10.9	3.2	1014
Oct 2, 1978	0.01	24.8	9.4	3.3	1013
Oct 3, 1978	0.00	24.7	9.3	2.4	1012
Oct 4, 1978	0.00	24.5	10.5	2.2	1012
Oct 5, 1978	0.00	21.4	11.2	3.9	1014
Oct 6, 1978	0.00	18.0	10.7	3.4	1017
Oct 7, 1978	0.20	18.8	9.8	2.4	1016
Oct 8, 1978	0.06	20.9	9.2	2.2	1014
Oct 9, 1978	0.01	19.9	10.4	2.8	1016
Oct 10, 1978	0.00	20.4	10.2	2.6	1019
Oct 11, 1978	0.00	21.5	9.0	1.3	1017

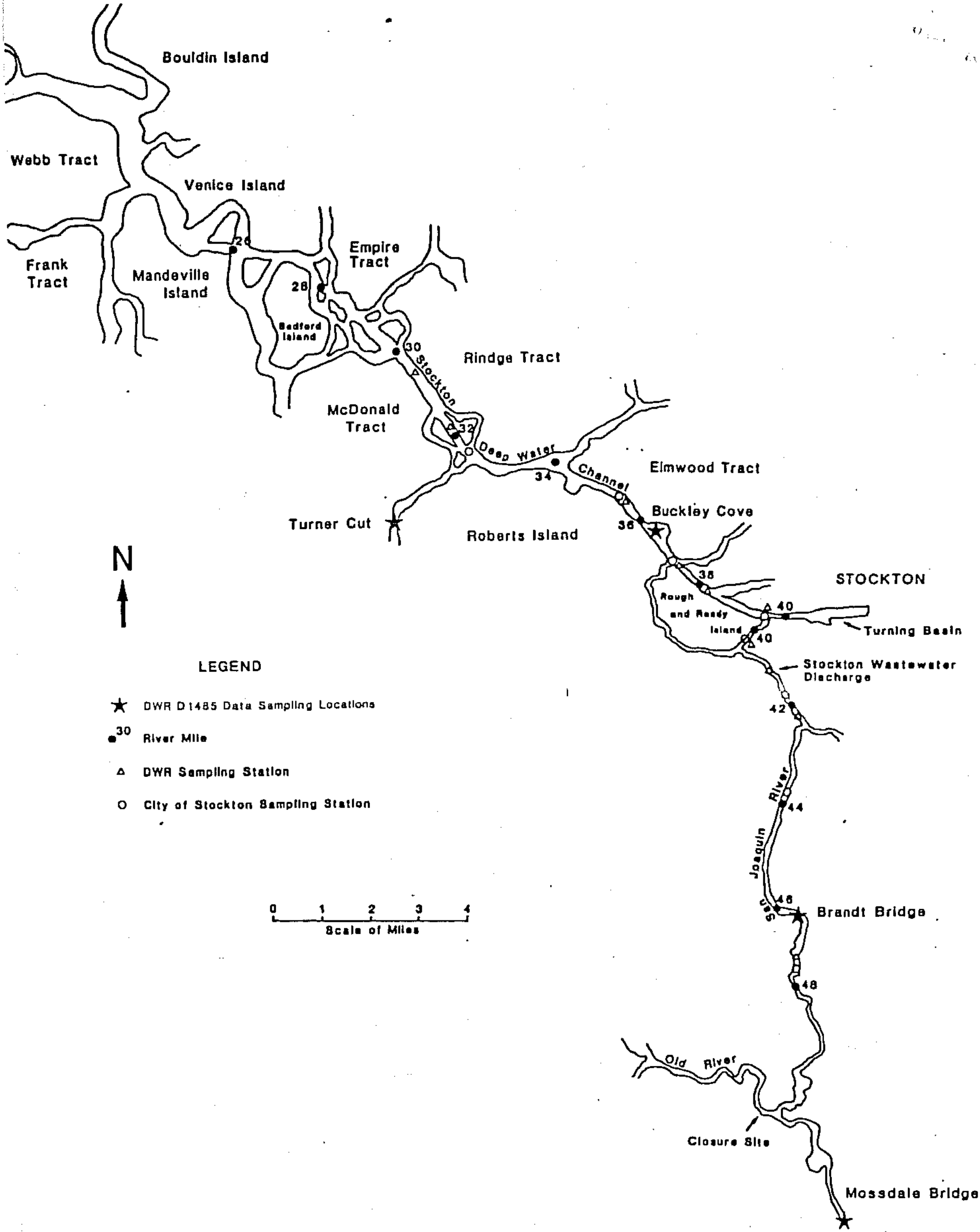


FIGURE IV-17. SAMPLING LOCATIONS
SAN JOAQUIN RIVER AND STOCKTON SHIP CHANNEL

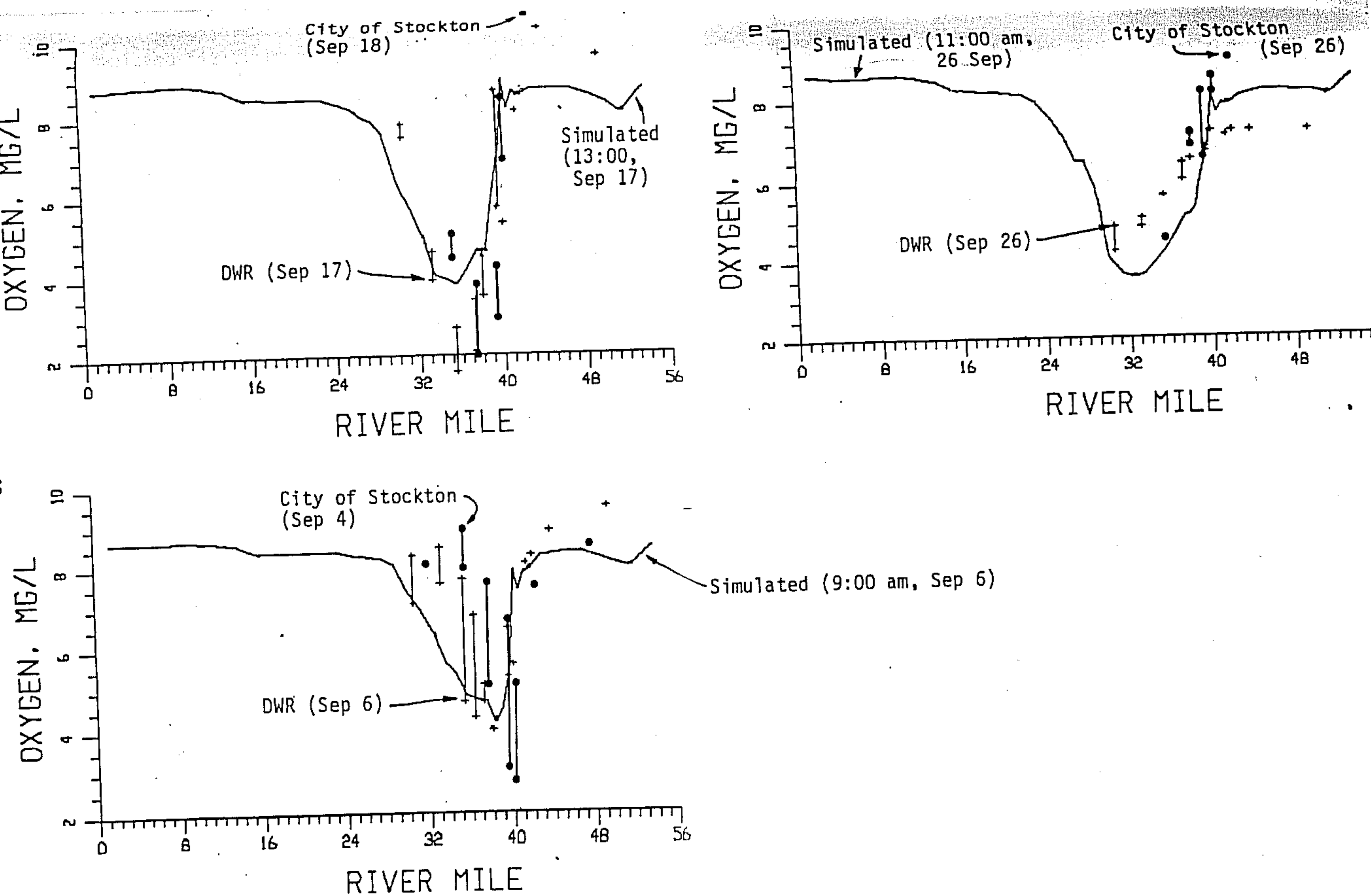


FIGURE IV-18. COMPUTED AVERAGE WATER COLUMN AND OBSERVED NEAR SURFACE AND BOTTOM DISSOLVED OXYGEN DURING SEPTEMBER 1-26, 1974 CALIBRATION PERIOD

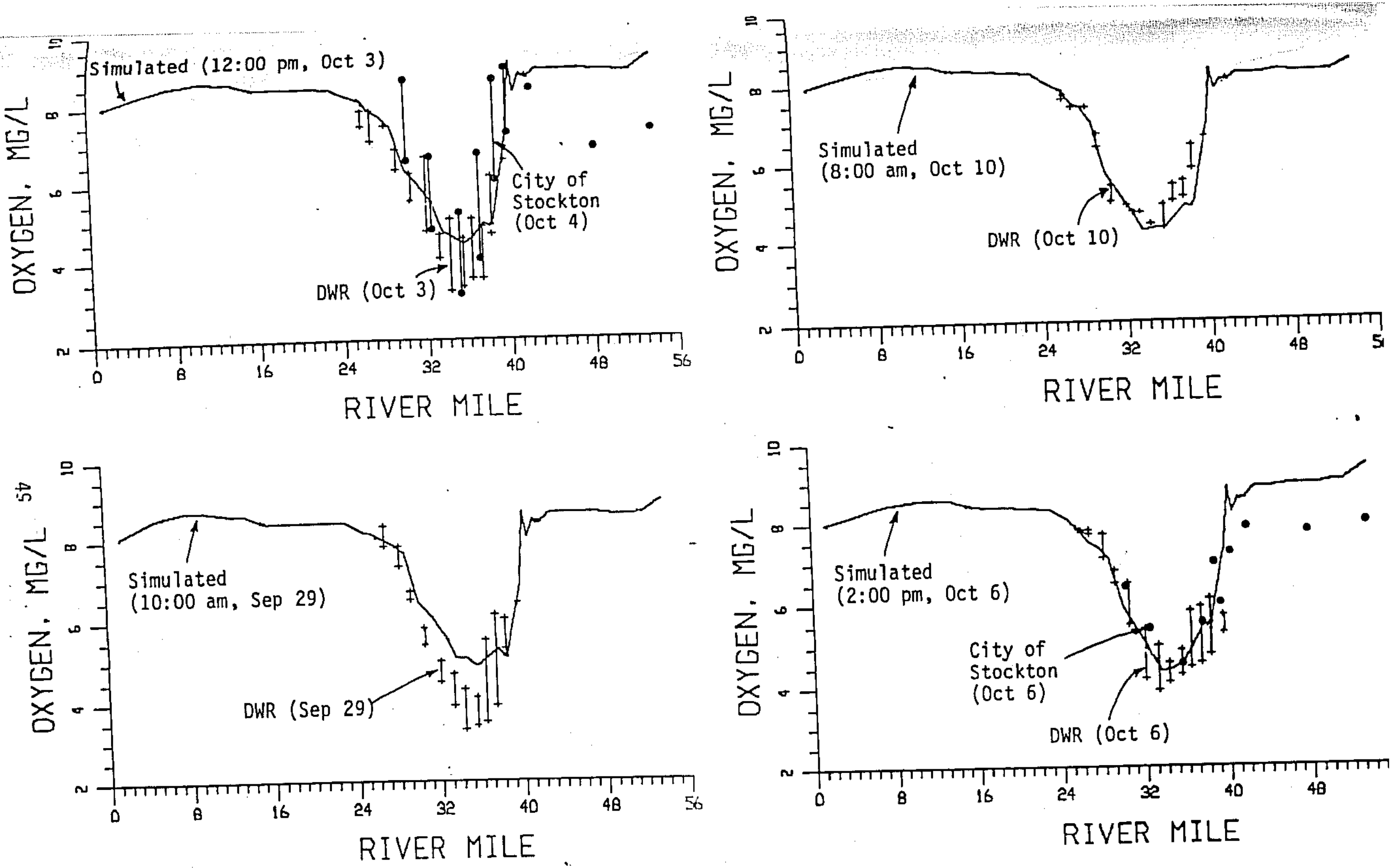


FIGURE IV-19. COMPUTED AVERAGE WATER COLUMN AND OBSERVED NEAR SURFACE AND BOTTOM DISSOLVED OXYGEN DURING SEPTEMBER 26 - OCTOBER 10, 1978 VALIDATION PERIOD

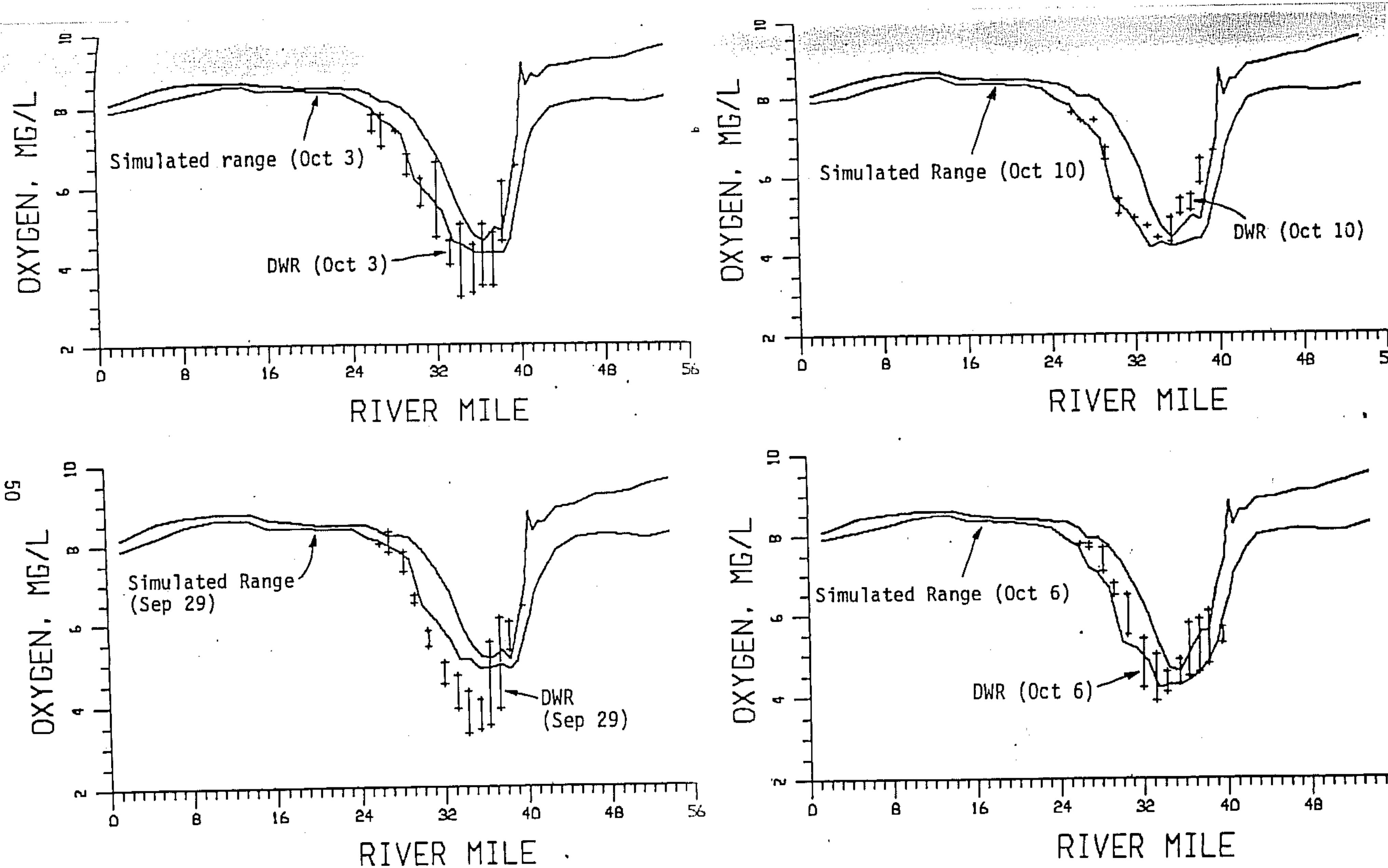


FIGURE IV-20. COMPUTED DAILY MAXIMA AND MINIMA, AND OBSERVED NEAR SURFACE AND BOTTOM DO FOR SEPTEMBER 26 - OCTOBER 10, 1978 VALIDATION PERIOD

CHAPTER V

WATER QUALITY MODEL SENSITIVITY AND EFFECTS OF STOCKTON SHIP CHANNEL DREDGING

V.1 WATER QUALITY MODEL SENSITVITY ANALYSES

The intent of the sensitivity analysis was to determine the magnitude of the effect of various environmental factors on the model representing the dissolved oxygen resources of the Delta and Stockton ship channel. Based on a good understanding of what affects DO in the Delta and experience gained in the calibration phase of this project, the models sensitivity to the following model characteristics were examined.

1) Depth of light penetration
2) Benthic BOD
3) Stockton wastewater facility effluent quality (SRWWCF)
4) San Joaquin River quality upstream of Stockton
5) DO coupling with phytoplankton and detritus
6) Method of calculating inflow estimates

Sensitivity analyses were carried out for the September 26 - October 10, 1978 test period. 1977 channel geometries were used.

Depth of Light Penetration

Algae populations are light-limited in the Stockton Ship Channel. Depth of light penetration is input to the water quality model on a node by node basis, or by zones. Inaccurate specification of the light penetration parameter can cause simulated algae populations to boom or bust.

Figure V-1 illustrates the effects of doubling the 1% light penetration depth from 2 feet to 4 feet. Algae 1 (diatoms) survive farther downstream in the channel when light penetration increases. Oxygen levels are consistently higher throughout the channel. It is interesting to note that the largest increase in both Algae 1 and DO occur below mile 32. Increased photosynthetic activity in the northern Delta result in higher concentrations of these parameters in the water being drawn south from the Sacramento River to the State and Federal pumps. It appears that improved water clarity would have the greatest effect in the shallower channels and that the Stockton ship channel is too deep to be affected by a change in clarity of this magnitude. Increases in the 1% light penetration significantly beyond 4 feet would be required to affect a major increase in the algae and DO concentrations in the Ship Channel.

Carbonaceous BOD is unaffected by the change in the depth of 1% light penetration. Algae 2 was not significantly affected by light penetration since most of the phytoplankton of SRWWCF origin remained in the Ship Channel where photosynthetic activity was less sensitive to the doubling of light penetration.

Benthic BOD

Benthic BOD loads are specified as benthic sink rates on a node by node or zonal basis. Estimates of benthic BOD are highly variable but generally range from 100 to 2000 mg/m^2/day for running river sections (4). Measurements by the California Department of Fish and Game and the EPA (7) indicated that the benthic BOD ranged from near zero to 1000 mg/m^2/day in the ship channel. Figure V-2 illustrates the effect of 1000 mg/m^2/day of benthic BOD in the ship channel from Webb Tract to the Turning Basin (nodes 11 to 31). The maximum decrease in the simulated dissolved oxygen concentration was aproximately .6 mg/L. This relatively small impact coupled with the uncertainty of the magnitude led to the decision to calibrate the model assuming zero benthic demand. Carbonaceous BOD and algae were unaffected by the addition of benthic BOD.

Stockton Regional Waste Water Control Facility Effluent Quality

The SRWWCF effluent prior to upgrading in 1978 was a major source of phytoplankton, suspended solids, nutrients and BOD. To evaluate the impact that the SRWWCF had on water quality within the ship channel, the effluent water quality was made similar to the San Joaquin River quality upstream of the discharge location. Using the upstream San Joaquin River quality had the effect of completely removing the discharge without requiring rerunning the hydrodynamic simulation with the discharge removed. Results are presented in Figure V-3. Algae 2 and detritus are reduced significantly and the characteristic oxygen sag in the channel is improved. The minimum computed DO concentration is increased from 4.2 mg/L to about 5.7 mg/L by removing the effluent. The Algae 1 actually increased slightly when the SRWWCF was removed due to the decrease in Algae 2 and detritus. The decrease in algae and detritus of SRWWCF origin increased the depth of light penetration which stimulates phytoplankton growth. This analysis demonstrates the importance of the SRWWCF discharge on the oxygen resources of the Stockton Ship Channel and the importance of accurate specification of the water quality of the effluent.

San Joaquin River Quality

Similarly, the San Joaquin River inflow is a major source of material which contributes to the degradation of DO in the ship channel. Figure V-4 illustrates the result of San Joaquin River quality being made similar to Sacramento River quality at Greens Landing. Algae 1 and BOD are significantly decreased. Oxygen sag in the ship channel was greatly reduced with the minimum computed DO concentration increasing 2.5 mg/L from 4.2 to 6.7 mg/L.

DO Coupling with Phytoplankton and Detritus

Results reported above indicate that algae concentrations from inflows make a significant contribution to the dissolved oxygen sag observed in the ship channel. To quantify the significance of algae and detritus (dead algae and other organic material), these parameters were uncoupled from dissolved oxygen by setting the appropriate model coefficients to zero. Resulting profiles are plotted in Figure V-5. The uncoupling of algae and detritus increases the minimum DO concentration from 4.2 mg/L to about 6 mg/L. This analysis shows that approximately half of the DO deficit can be attributed to phytoplankton and other particulate organic matter. The remaining DO deficit is caused by the carbonaceous BOD and nitrogenous BOD (ammonia decay). BOD and Algae 1 and 2 concentrations were unaffected since only the coupling with DO was removed.

Calculation Method for Inflow Estimates

The proceeding evaluation of model sensitivity demonstrates that the San Joaquin River and SRWWCF discharge have a profound effect on the DO within the ship channel. The San Joaquin quality is subject to significant variation over time and the SRWWCF treatment plant has been upgraded since 1978. To evaluate the model's sensitivity to San Joaquin River quality within the range of the observation data and the before and after treatment plant upgrade quality, the following evaluation was made.

Three sensitivity runs were made using different estimates of San Joaquin River quality and Stockton wastewater effluent quality. Three alternative estimates were compared with the original inflow data base (CASE.1). The four sources of inflow quality data are described below:

1) CASE.1 - Typical inflow values were selected from September and October 1978 STORET data used for the validation simulations.

2) CASE.2 - DWR data at Mossdale Bridge from September and October, 1974-1981, was arithmetically averaged. Dry year 1977 was excluded. Only PO_4-P, detritus, BOD, NH_3-N, DO, Algae1 and Algae2 at Mossdale Bridge were changed. All other inflow specifications same as CASE.1 (see Table V-1 and Table V-2).

3) CASE.3 - Worst case DWR data at Mossdale Bridge were selected. Data for September 25, 1978 was used for detritus, NH_3-N, DO, Algae1, and Algae2. All other inflows are the same as CASE.1.

4) CASE.4 - The Corps supplied flow weighted means of PO_4-P, detritus, BOD, NH_3-N, and Algae2 for SRWWCF effluent <u>after</u> the facility upgrade. All other inflows are the same as CASE.1.

Results of the three sensitivity runs are shown in Figures V-6 through V-8. In each case, the alternative inflow estimates are compared with the original validation inflow quality. Average concentrations from the DWR nine year period of record did not differ significantly from STORET derived concentrations for the San Joaquin River at the Mossdale Bridge (Table V-2). The resulting profiles of DO, algae, and BOD were also similar (Figure V-6). The worst case estimate of San Joaquin River quality resulted in significantly lower DO concentrations in the ship channel. With the worst case estimates of San Joaquin River inflow quality (see Figure V-7), the minimum computed DO in the ship channel was reduced to 3.2 mg/L.

Results of the SRWWCF upgrade are presented in Figure V-8. Algae 2 is significantly reduced after the upgrade. Consequently, dissolved oxygen downstream of the SRWWCF is increased.

Inflow quality estimates have a dramatic effect on model results. For dissolved oxygen simulation, particular attention was given to algae concentrations, detritus, and BOD.

V.2 EFFECTS OF SHIP CHANNEL DREDGING ON HYDRODYNAMICS AND WATER QUALITY

Model Representation

The San Joaquin River and Stockton Ship Channel geometry used in the calibration and verification phase of this project was based on the 1977 Corps soundings. These soundings were used since they were most representative of the conditions which prevailed during the 1978 calibration period and 1974 validation period. For the dredging effects evaluation phase of the project the channel geometry was based on the 1982 Corps soundings. Two sets of channel geometry were derived from these soundings. For the pre-dredging predictions, the 1982 soundings were truncated at 30 feet except in the sediment trap where the soundings were truncated at 35 feet. The 30 and 35 foot depths were the authorized depth of the channel and sediment trap prior to the 35 and 40 foot authorization. To represent post-dredging conditions the 35 foot (40 foot in the sediment trap) dredging template was superimposed over the 1982 soundings.

Hydraulic Effects

Simulations were performed under pre-dredging and post-dredging conditions to determine the hydraulic impact of the deeper channel. Figure V-9 is a comparison of the computed stage and velocity for a typical node and channel. Note that the computed stages fall on the 45 degree line indicating that the channel deepening has a negligible effect on tidal stage and phase. The effect on velocities, however, is significant. The plot shows that the post-dredging velocities are reduced throughout the tide cycle. The comparisons of the computed velocities fall on a straight line indicating that the amount of the reduction is constant throughout the tidal cycle. The post-project velocity for this channel is approximately 86% of that for the pre-dredging case. The reduction in velocity coupled with no change in stage is typical of the other channels and nodes representing the Stockton Ship Channel. Since the dredging has a negligible effect on tidal stage and therefore does not change hydraulic gradients, channel deepening will have only a very minor effect on the hydrodynamics of the other Delta channels.

The effects of dredging on the net flow, maximum velocity, ratio of the maximum velocity and the flow induced reaeration coefficient (based on the O'Connor and Dobbins relationship) in the channels near Stockton are shown in Table V-3. A review of this table shows that the net flows are almost unaffected by the channel deepening, however, the velocities and reaeration coefficient are reduced typically 10% and 20% respectively. The reduction in velocity will increase the hydraulic residence time within the ship channel. The decreased residence time coupled with the reduced reaeration will likely reduce oxygen levels in the Stockton Ship Channel.

Water Quality Effects

To quantify the effects of the channel deepening on water quality the model was run for pre- and post-dredging conditions using the model representation based on the 1982 sounding data. The water quality model was run for both the September-October 1978 period and the September 1 through 26 1974 period. The computed daily average dissolved oxygen concentration on October 10, 1978 and September 26, 1974 for the pre- and post-dredging conditions and inflow data used for calibration and validation are presented in Figure V-10. Final day results were used to minimize the influence of specified initial conditions. Note that for both days the maximum reduction in DO due to the deeper channel is approximately 0.5 mg/L.

These results shown in Figure V-10 are for a 30 foot and 35 foot channel section. Many of the channels are already deeper than the 30 foot authorized depth, therefore the actual reduction in DO due to deepening to 35 feet from the existing condition would be less. Figure V-11 shows the DO profiles for the existing channel and the 35 foot channel. The maximum reduction due to dredging relative to existing conditions is approximately .25 mg/L.

The sensitivity analyses indicated that specified inflow quality can have a large effect on simulation results. To evaluate the range in DO which would be expected under post dredging conditions, the "worst case" (see Table V-2) San Joaquin River quality was simulated under post dredging channel conditions. In addition to the variation in San Joaquin River quality, the SRWWCF plant has been upgraded since 1978, therefore pre and post upgrade effluent quality was simulated. The effects of these variations in San Joaquin River quality and SRWWCF effluent quality on DO within the ship channel are shown in Figure V-12. The results for October 1978 hydrology and these three inflow quality conditions are compared with the results for average 1974-1981 (1977 excluded) San Joaquin River quality and average pre-upgrade SRWWCF effluent quality.

Post-dredging simulation results for worst case San Joaquin River quality shows that the average dissolved oxygen concentrations would have been reduced to a minimum of 3.0 mg/L with the SRWWCF operating under 1978 conditions.

The effluent quality of the SRWWCF upgraded plant improved dissolved oxygen concentrations in the ship channel significantly. Even with the worst case San Joaquin River quality, the minimum DO in the ship channel would be above that computed for the 1978 base conditions. The minimum DO computed for post-dredging conditions with the upgraded treatment plant is 5.2 mg/L and 4.3 mg/L for the average 1974-1981 (excluding 1977) and worst case San Joaquin River inflow quality respectively.

V.3 DISSOLVED OXYGEN REQUIREMENTS FOR REVERSAL OF DREDGING EFFECTS

In order to balance the reduced oxygen levels predicted for the dredged channel, oxygen could be added to the ship channel system. Several alternatives are available to increase oxygen levels in the ship channel including flow alteration and mechanical aeration. Determination of the most feasible method for oxygen enhancement however, is beyond the scope of this contract.

To provide and estimate for the amount of additional oxygen needed to counter the effects of the deeper ship channel, the model was run for the dredged channel configuration and a total of 7500 pounds of oxygen added per day to a limited reach of the Stockton Ship Channel. The area of forced oxygen input was bounded by river miles 33 and 38 (nodes 21-25) and coincided with the area of maximum computed sag on October 10, 1978. Results for both 1974 and 1978 test period hydraulics and inflow quality are shown in Figure V-13. The 7500 pounds of oxygen added by induced aeration increased the daily average minimum DO approximately 1.1 mg/L from 4 mg/L to 5.1 mg/L for 1978 test period. Assuming the increase is proportional to the amount of oxygen input over the 1.1 mg/L range, approximately 3400 pounds of oxygen per day would be required to counter the .5 mg/L reduction in DO caused by the increased depth in the Stockton Ship Channel.

Proper management will be important in prescribing an aeration plan. This fact is demonstrated by the simulation results for September 26, 1974, which indicates an addition of 7500 pounds of oxygen per day between river miles 33 and 38 would result in an increase in the minimum DO of only .65 mg/L. The effect of aeration was less pronounced since the low point in the DO sag occurred further downstream due to larger net San Joaquin River flows. Forced aeration would be the most effective if the location and intensity could vary with the hydrology conditions to coincide to the region of maximum DO depression.

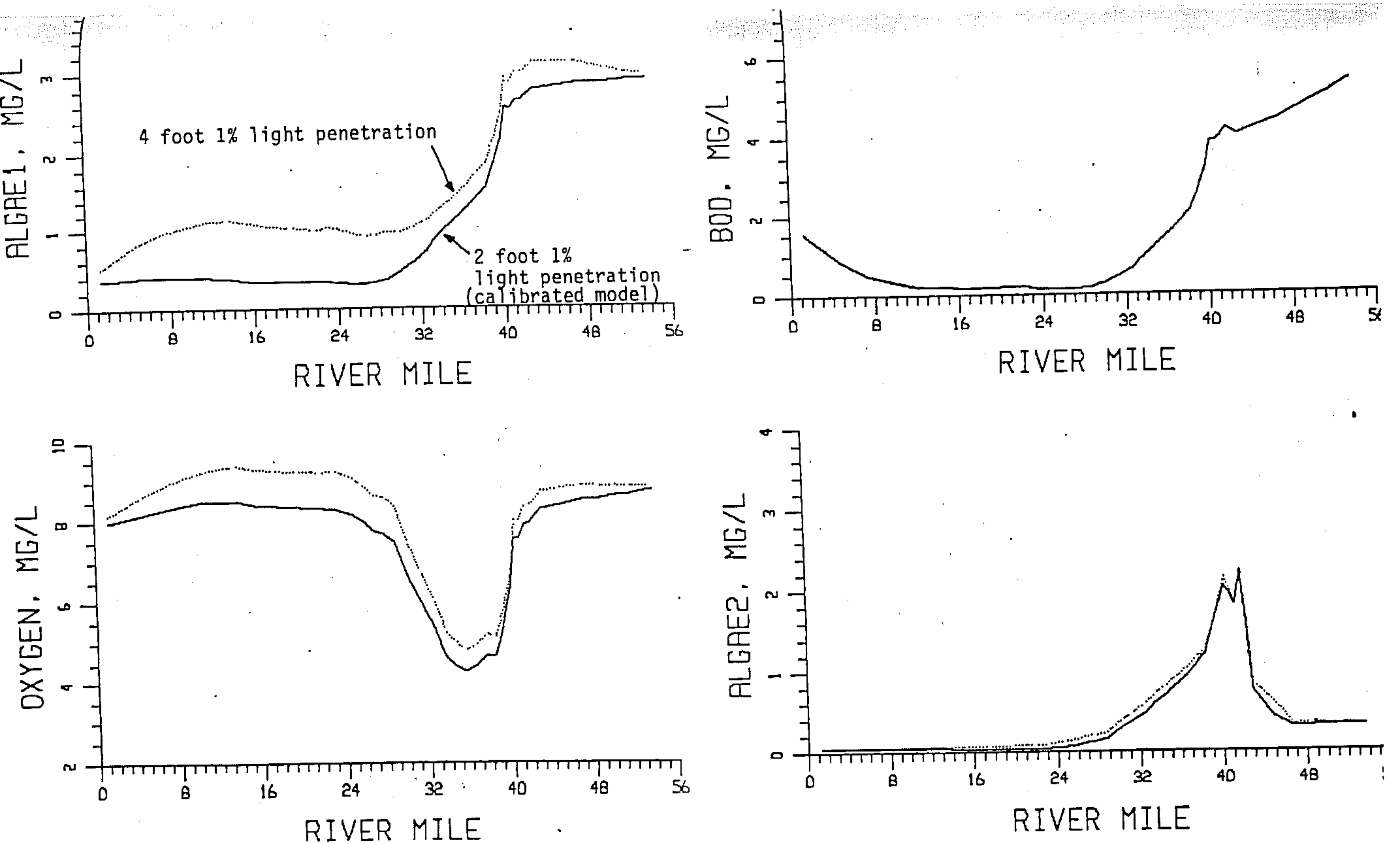


FIGURE V-1. MODEL SENSITIVITY TO THE DEPTH OF 1% LIGHT PENETRATION. RESULTS SHOWN ARE AVERAGE DAILY QUALITY ON OCTOBER 10, 1978.

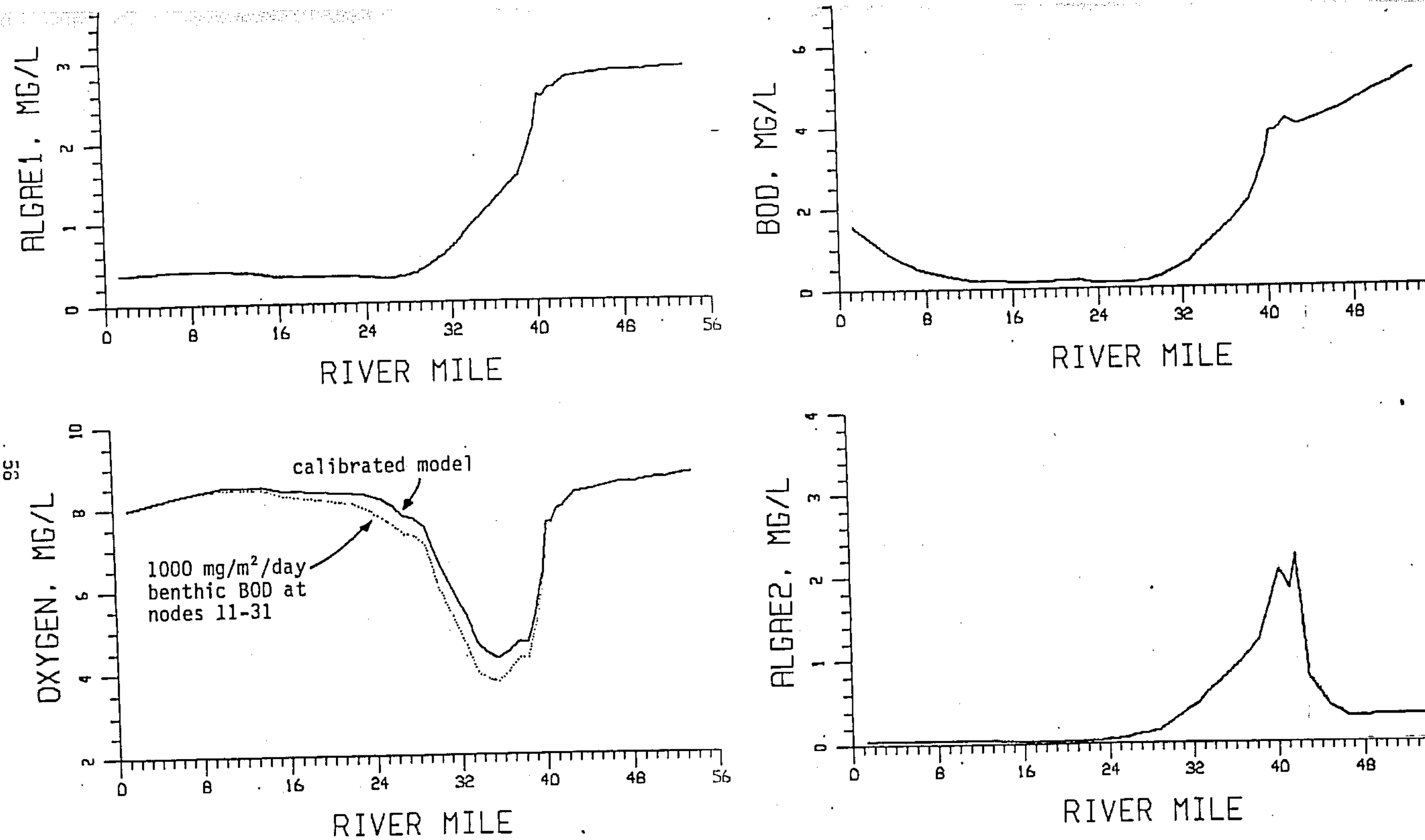


FIGURE V-2. MODEL SENSITIVITY TO BENTHIC BOD ADDED AT NODES 11 THROUGH 31.
RESULTS SHOWN ARE AVERAGE DAILY QUALITY ON OCTOBER 10, 1978.

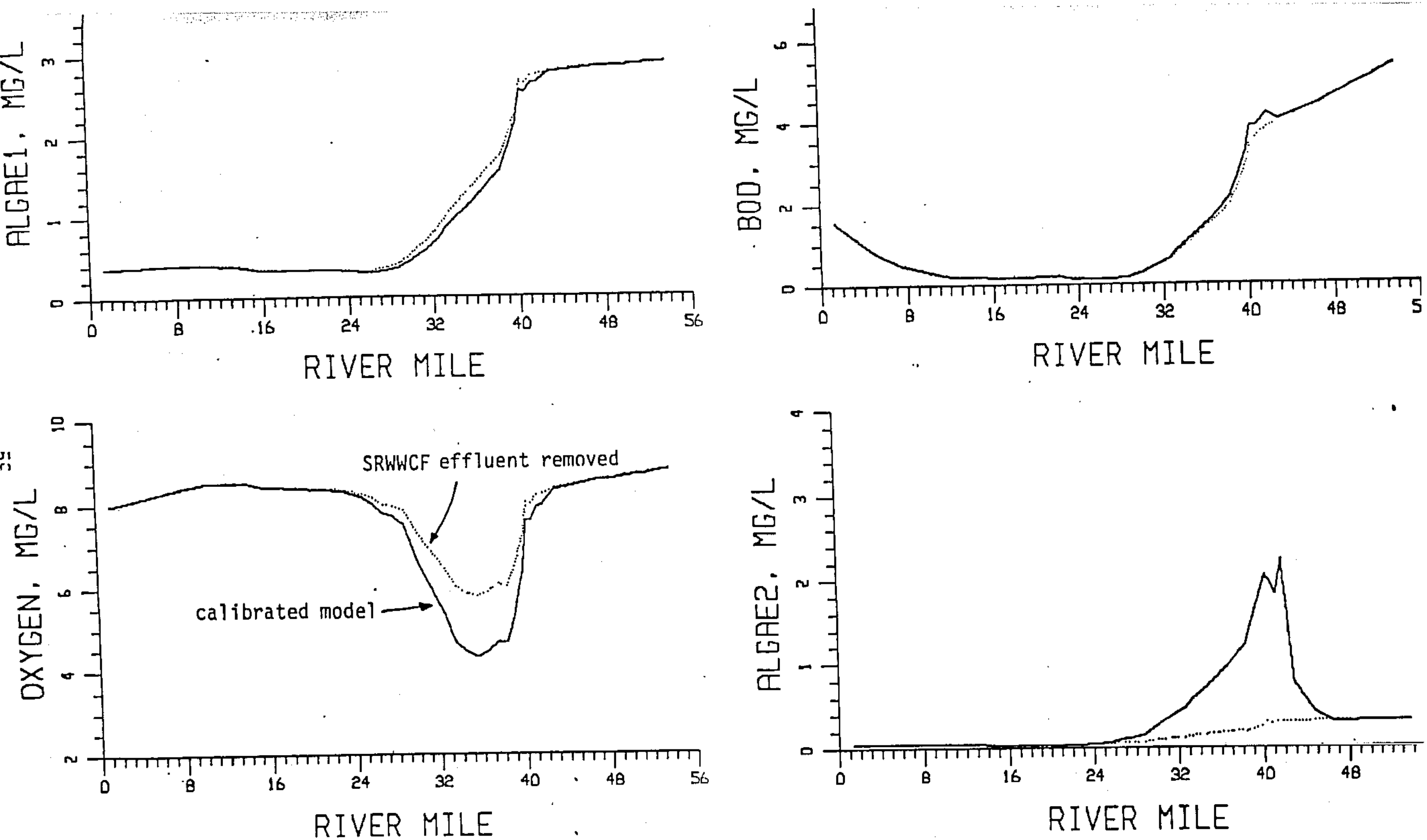


FIGURE V-3. MODEL SENSITIVITY TO SRWWCF EFFLUENT QUALITY. RESULTS SHOWN ARE AVERAGE DAILY QUALITY ON OCTOBER 10, 1978.

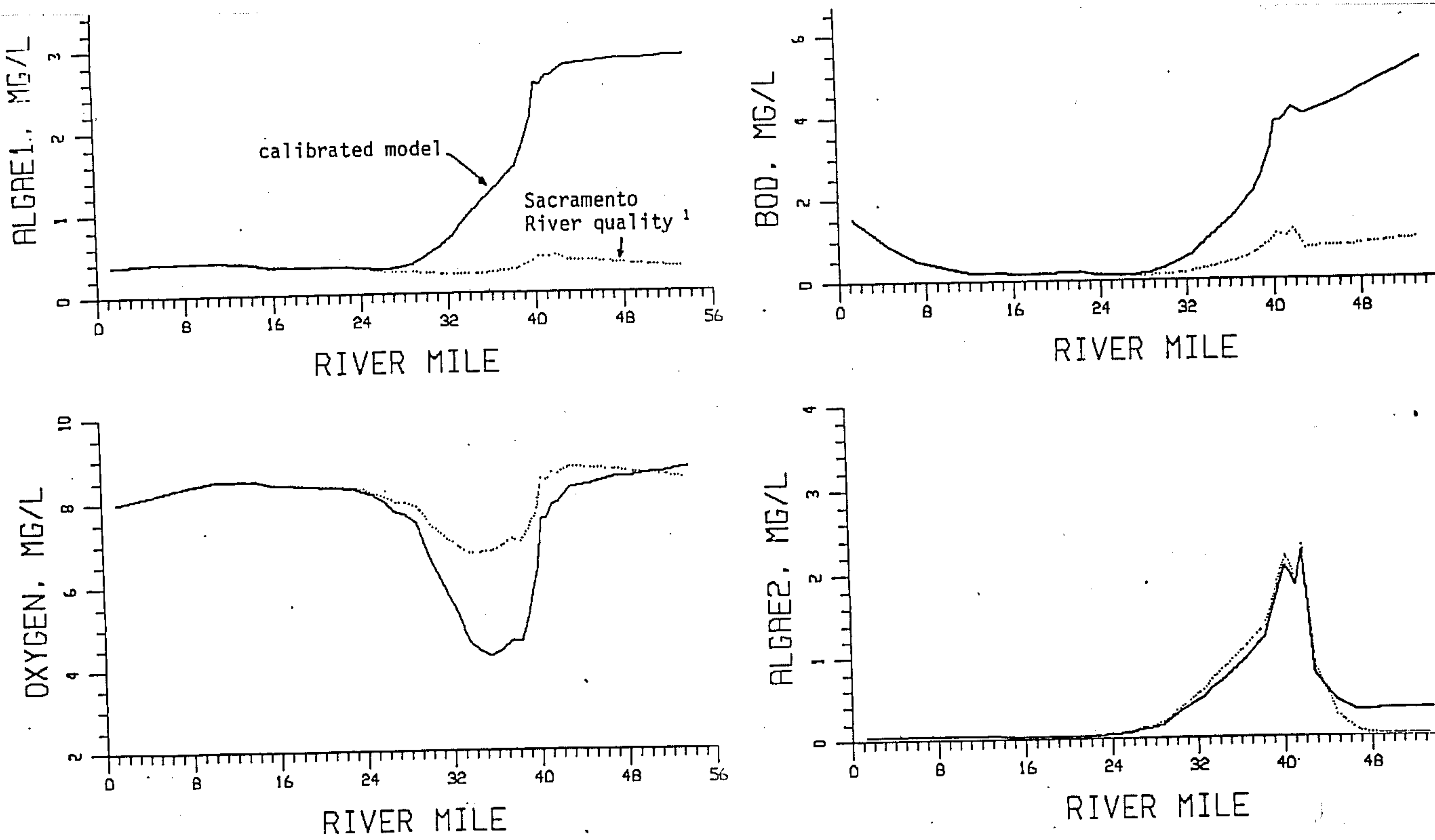


FIGURE V-4. MODEL SENSITIVITY TO SAN JOAQUIN RIVER QUALITY.[1] RESULTS SHOWN ARE AVERAGE DAILY QUALITY ON OCTOBER 10, 1978.

[1] The quality of the San Joaquin River at Mossdale was replaced by the quality of the Sacramento River at Greens Landing

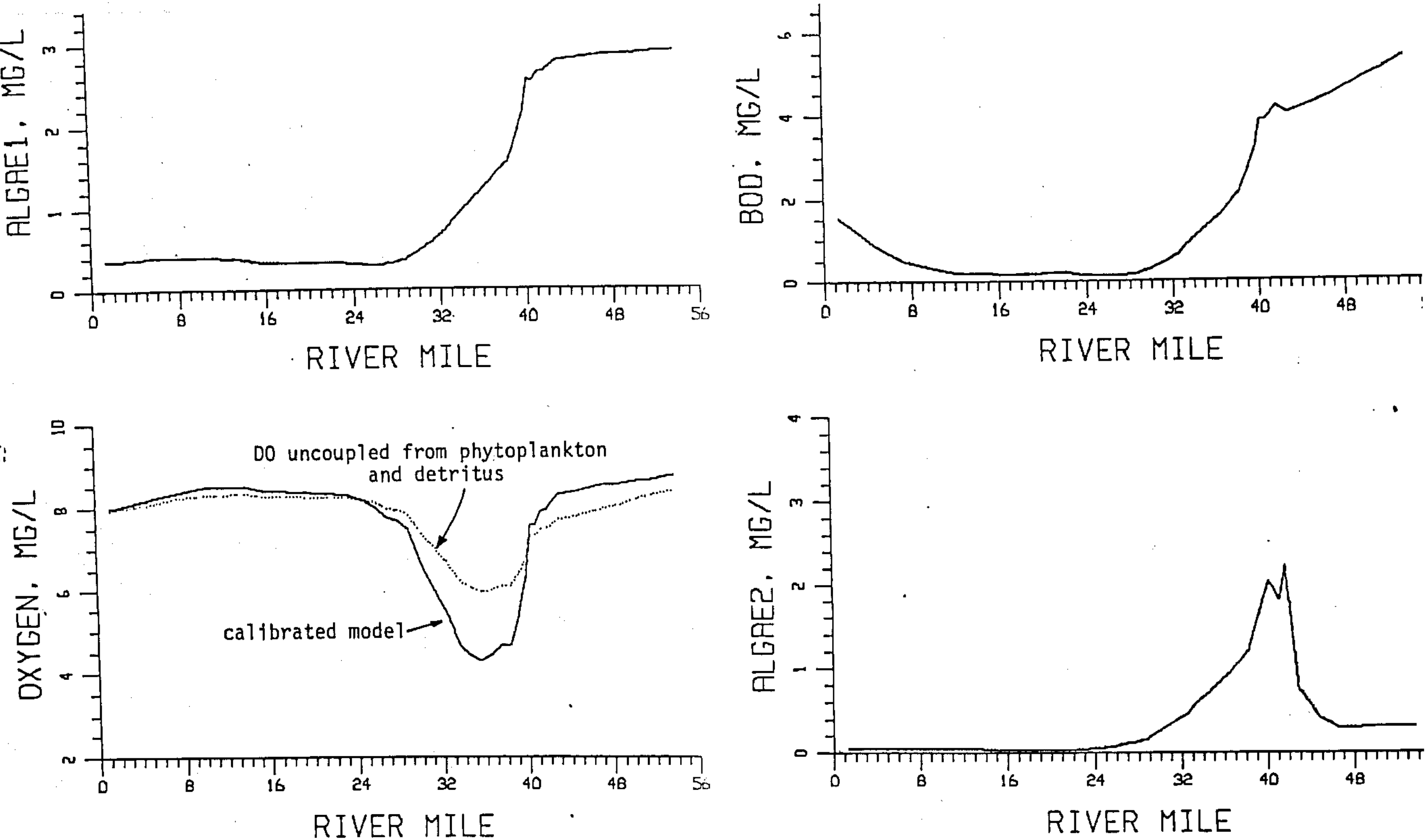


FIGURE V-5. EFFECT OF PHYTOPLANKTON AND DETRITUS ON DISSOLVED OXYGEN. RESULTS SHOWN ARE AVERAGE DAILY QUALITY ON OCTOBER 10, 1978

TABLE V-1

DEPARTMENT OF WATER RESOURCES
MOSSDALE BRIDGE DATA (NODE 163)
SEPTEMBER AND OCTOBER, 1974-1981

Time Period	Chlor a (µg/L)	Pheo a (µg/L)	Dissolved NH_3-N (mg/L)	Dissolved Ortho-PO_4-P (mg/L)	DO (mg/L)	BOD-5 day (mg/L)
9- 4-74	37.00	16.00	0.04	0.07	7.70	3.50
9-18-74	50.00	16.00	0.03	0.07	7.70	
10- 2-74	23.00	15.00	0.05	0.06	7.00	3.60
10-16-74	21.00	17.00	0.06	0.08	7.10	
1974 mean	32.75	16.00	0.05	0.07	7.37	3.55
9-11-75	34.74	9.27	0.04	0.07	7.50	3.30
9-25-75	30.11	12.74	0.03	0.07	7.30	
10-10-75	9.42	9.23	0.04	0.06	7.90	
10-23-75	14.82	5.56	0.00	0.02	8.70	2.40
1975 mean	22.27	9.20	0.03	0.06	7.85	2.85
9-14-76	46.32	15.06	0.08	0.13	6.60	5.50
9-27-76	27.79	13.90	0.42	0.16	4.90	
10-12-76	28.56	11.97	0.39	0.13	5.50	
10-28-76	16.21	9.27	0.32	0.06	7.60	4.80
1976 mean	29.72	12.55	0.31	0.12	6.15	5.15
1977	Drought conditions					
9-11-78	36.44	15.44	0.09	0.10	7.90	
9-25-78	61.75	19.77	0.03		9.20	
10-10-78	12.97	8.80	0.10	0.12	7.60	
10-23-78	8.03	5.87	0.17		7.70	
1978 mean	29.80	12.47	0.10	0.11	8.10	
9-11-79	36.13	13.20	0.07	0.14	6.90	
9-24-79	25.01	13.55	0.11		6.20	
10- 9-79			0.09	0.12	6.80	
10-22-79	5.87	2.82	0.11		7.60	
1979 mean	22.34	9.86	0.10	0.13	6.88	
9- 2-80	28.04	11.80	0.06	0.12	7.50	
9-15-80			0.02		8.00	
10-14-80			0.07	0.08	8.40	
10-27-80	2.23	3.90	0.10		8.70	
1980 mean	15.14	7.85	0.63	0.10	8.15	
9- 1-81			0.02	0.13	9.50	
9-15-81			0.03		8.70	
10- 5-81			0.05	0.12	7.90	
10-19-81			0.20		7.80	
1981 mean			0.08	0.13	8.50	

TABLE V-1
(continued)

Time Period		Chlor $\underline{a}$ (μg/L)	Pheo $\underline{a}$ (μg/L)	Dissolved NH_3-N (mg/L)	Dissolved Ortho-PO_4-P (mg/L)	DO (mg/L)	BOD-5 day (mg/L)
Overall Mean	$\bar{x}$	26.45	11.72	0.10	0.09	7.57	3.41
Standard Deviation	S	15.32	4.56	0.10	0.03	1.01	1.26

NOTES:

1. The drought year of 1977 was assumed atypical and excluded from the overall mean and standard deviation.

2. Numeric mean values are not flow weighted.

3. The ratio of 100 g algae to 1 g chlorophyll $\underline{a}$ was used to compute algal biomass (the ratio of algal biomass to chloropyll $\underline{a}$ ranges from 25 to 150(5) and is normally near 100).

4. Ninety percent of the total algal biomass was arbitrarily assumed to be Algae 1 and 10% assumed to be Algae 2.

5. The ratio of 100 g detritus to 1 g pheophyton $\underline{a}$ was used to compute detritus.

6. Ultimate carbonaceous BOD was set to 1.46 times the 5 day BOD. This factor is based on a laboratory decay rate of .23/day.

TABLE V-2

ALTERNATIVE INFLOW QUALITY SPECIFICATIONS
FOR WATER QUALITY MODEL INPUT DECK

Input Deck	Junc	Inflow (cfs)	TDS (mg/L)	NO_3-N (mg/L)	PO_4-P (mg/L)	Total Coliform (no/100ml)	Detrit (mg/L)	Ult C BOD (mg/L)	NH_3-N (mg/L)	Oxygen (mg/L)	Temp (°C)	Algae1 (mg/L)	Algae2 (mg/L)
Case.1[1]	163	2970-4120	800.0	0.75	0.15	1000	1.5	5.5	0.10	8.5	20.0	2.7	0.3
Case.2[2]	163				0.09		1.1	5.0	0.10	7.6		2.4	0.3
Case.3[3]	163						1.8		0.03	9.2		5.6	0.6
Case.1[1]	158	34-45	1000.0	0.35	7.00	100	25.0	13.0	2.00	6.0	22.0	2.0	40.0
Case.4[4]	158				1.16		4.5	11.7	1.09			0.5	9.0

[1] Derived from DWR STORET data (average), September and October 1978, and SRWWCF (pre-upgrade) monthly lab reports.

[2] Arithmetic average of DWR data, September and October, 1974-1981. Dry year 1977 excluded. Unspecified values, same as Case.1.

[3] "Worst case" San Joaquin inflow quality. DWR observed concentrations September 25, 1978. Unspecified values, same as Case.1.

[4] Flow weighted means, September and October 1979-1983 (after SRWWCF upgrade). Unspecified values, same as Case.1.

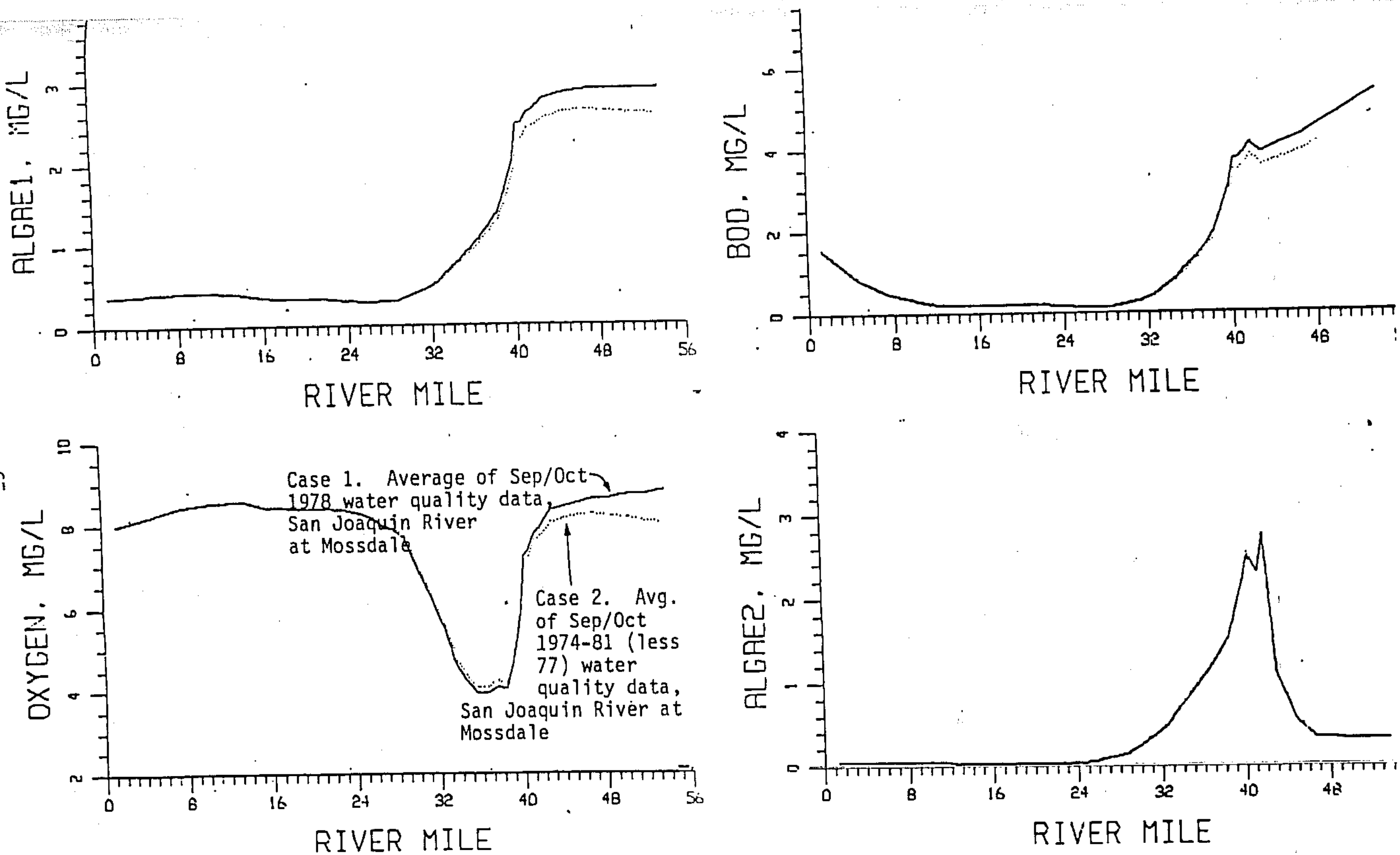


FIGURE V-6. MODEL RESULTS WITH SAN JOAQUIN INFLOW QUALITY ESTIMATED FROM 1978 STORET DATA (CASE 1), AND FROM 9 YEARS OF DWR DATA FOR SEPTEMBER AND OCTOBER (CASE 2). RESULTS SHOWN FOR CASE 1 ARE AVERAGE DAILY QUALITY ON OCTOBER 10, 1978.

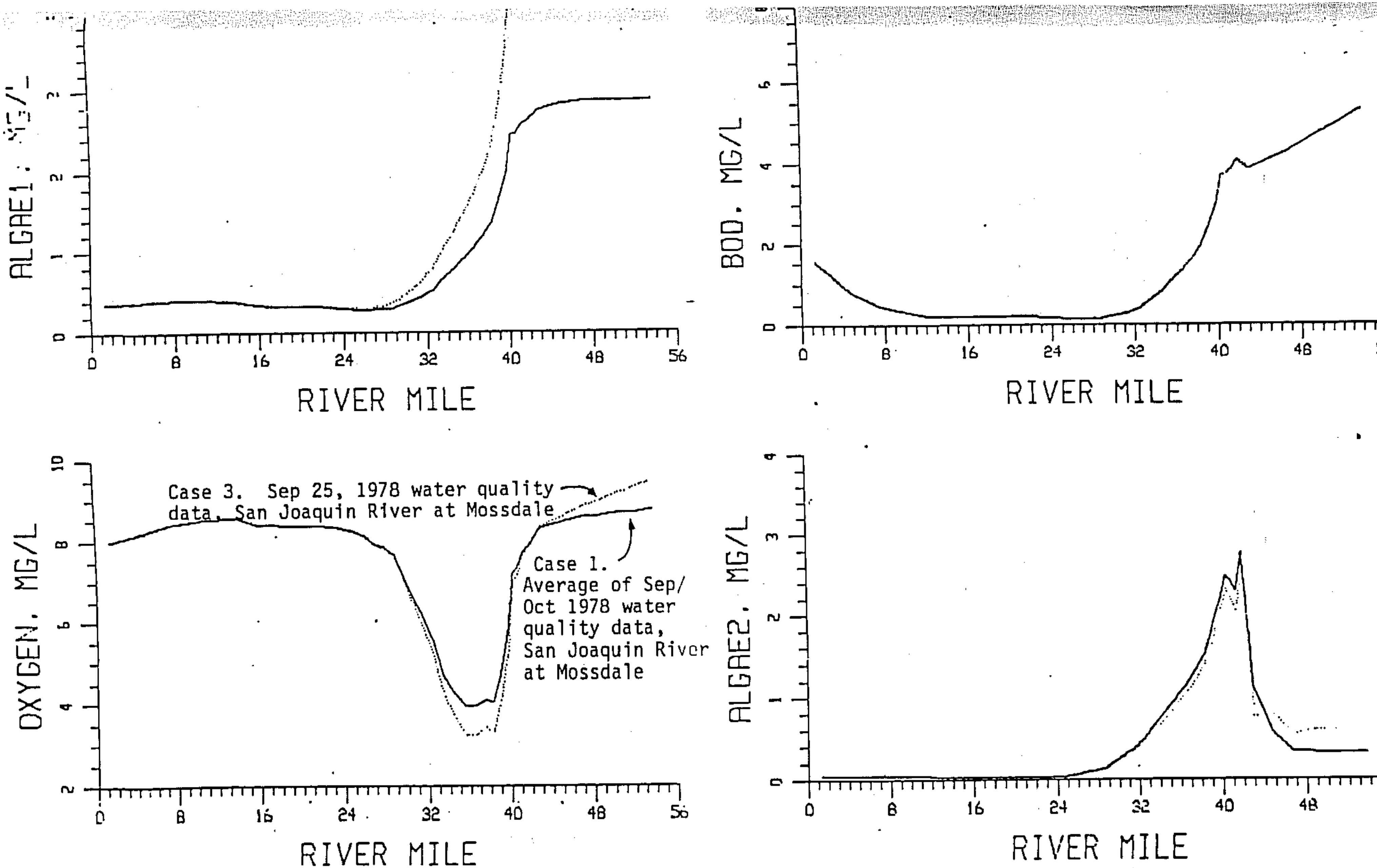


FIGURE V-7. MODEL RESULTS WITH SAN JOAQUIN INFLOW QUALITY ESTIMATED FROM 1978 STORET DATA (CASE 1) AND SEPTEMBER 25, 1978 DWR OBSERVED VALUES (WORST CASE) (CASE 3). RESULTS SHOWN FOR CASE 1 ARE AVERAGE DAILY QUALITY ON OCTOBER 10, 1978.

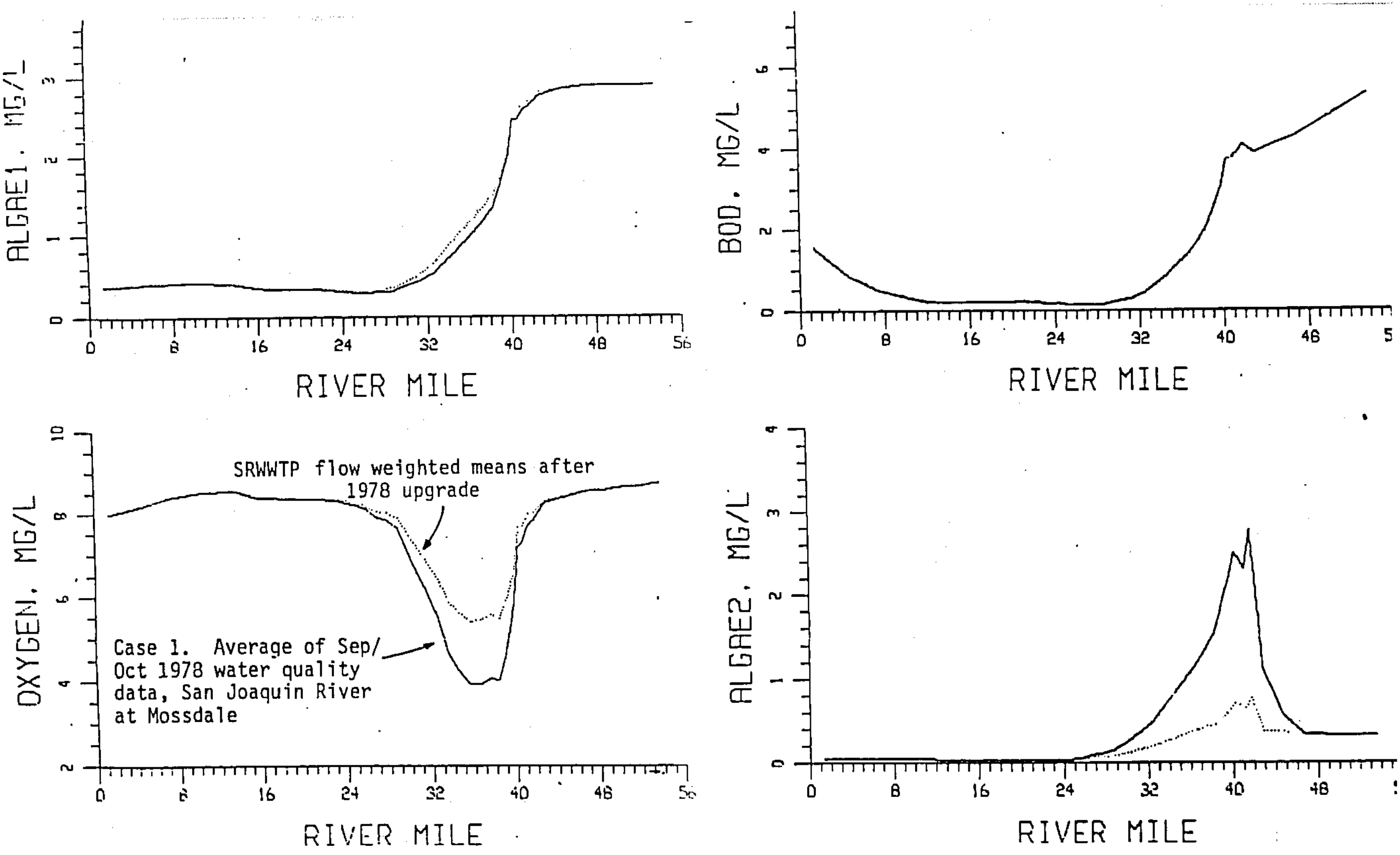
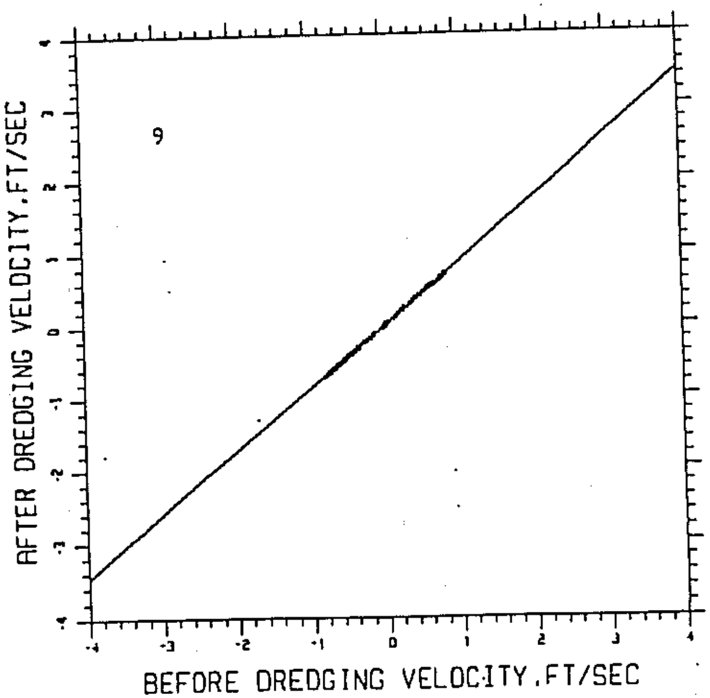
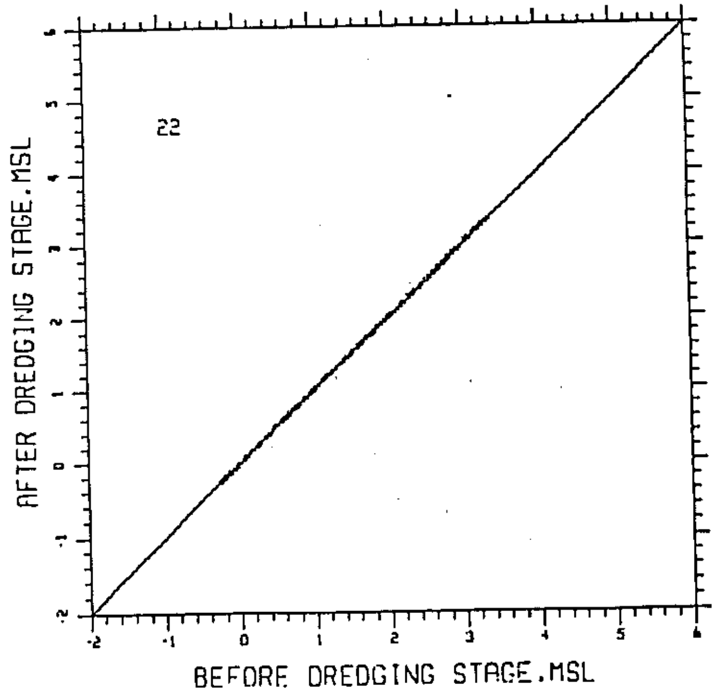


FIGURE V-8. MODEL RESULTS WITH SRWWCF PRE-UPGRADE EFFLUENT QUALITY ESTIMATED FROM 1978 SEPTEMBER AND OCTOBER MONTHLY REPORTS (CASE 1), AND FROM FLOW-WEIGHTED MEANS OF POST-UPGRADE DATA (CASE 4). RESULTS SHOWN ARE AVERAGE DAILY QUALITY ON OCTOBER 10, 1978.



Velocity in the Stockton Ship Channel
from node 22 to node 21



Stage in the Stockton Ship Channel
at node 22

FIGURE V-9

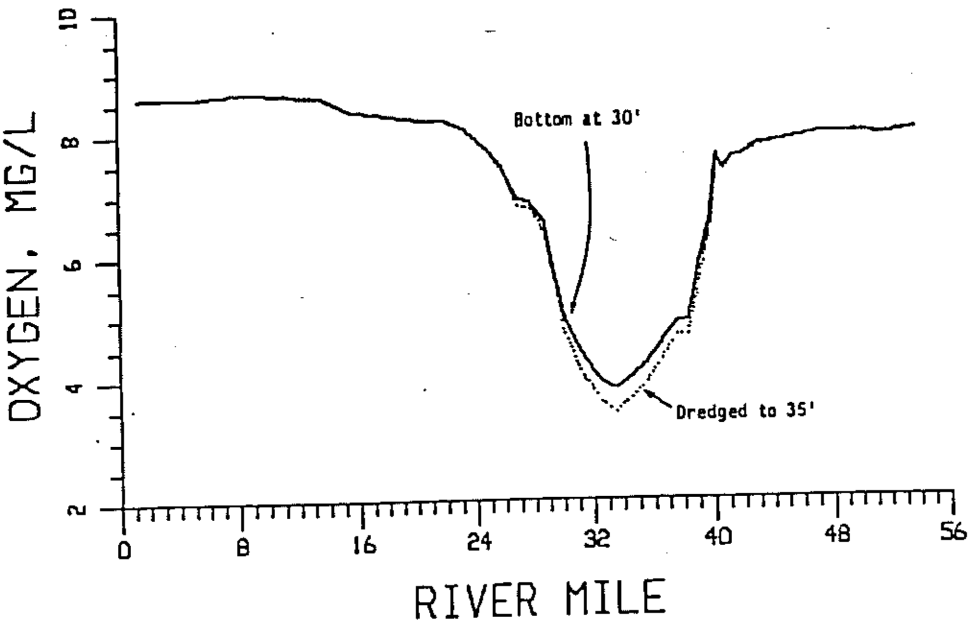
PREDICTED EFFECTS OF STOCKTON SHIP CHANNEL
DEEPENING ON VELOCITY AND STAGE
(PREDICTIONS FROM HYDRODYNAMIC MODEL)

TABLE V-3

PREDICTED EFFECTS OF DEEPENING ON THE HYDRAULIC CHARACTERISTICS OF THE STOCKTON SHIP CHANNEL

CHANNEL		NET FLOW, cfs		MAXIMUM VELOCITY, ft/sec		RATIO OF AFTER DREDGED VELOCITY TO BEFORE DREDGED VELOCITY	FLOW INDUCED REAERATION COEFFICIENT, 1/day	
Node to Node		Before Dredging	After Dredging	Before Dredging	After Dredging		Before Dredging	After Dredging
21	20	499	502	.77	.71	.915	.0613	.0507
22	21	504	506	.80	.70	.868	.0735	.0535
23	22	507	508	.65	.56	.871	.0564	.0419
24	23	512	513	.66	.61	.912	.0619	.0509
25	24	518	519	.56	.51	.916	.0668	.0630
26	25	419	421	.35	.33	.910	.0426	.0349
27	26	427	428	.28	.26	.915	.0370	.0308
28	27	433	434	.28	.25	.888	.0478	.0378
29	28	0	0	.08	.07	.878	.0172	.0133
30	29	0	0	.06	.05	.864	.0160	.0120

September 26, 1974



October 10, 1978

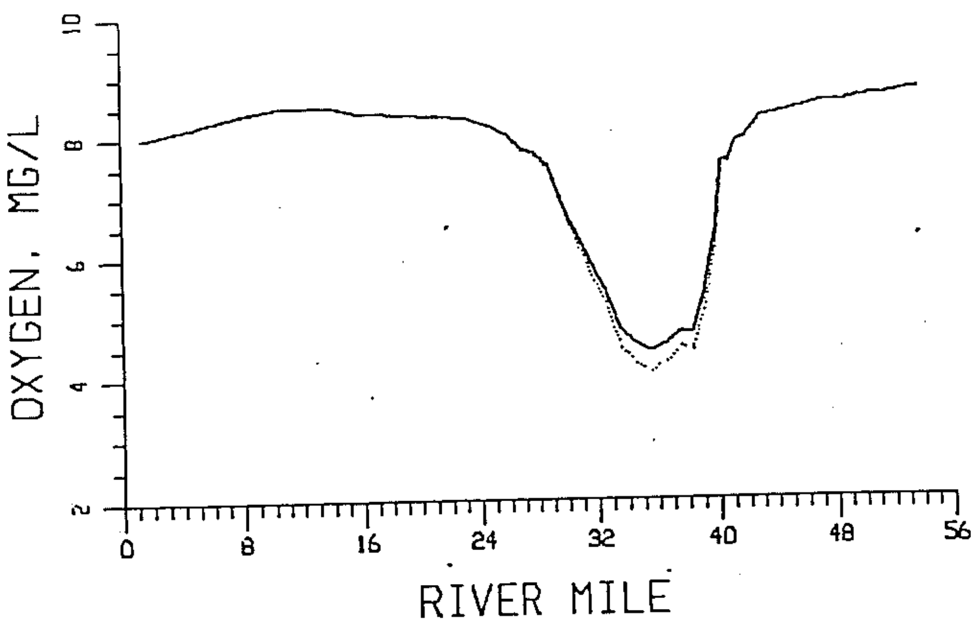
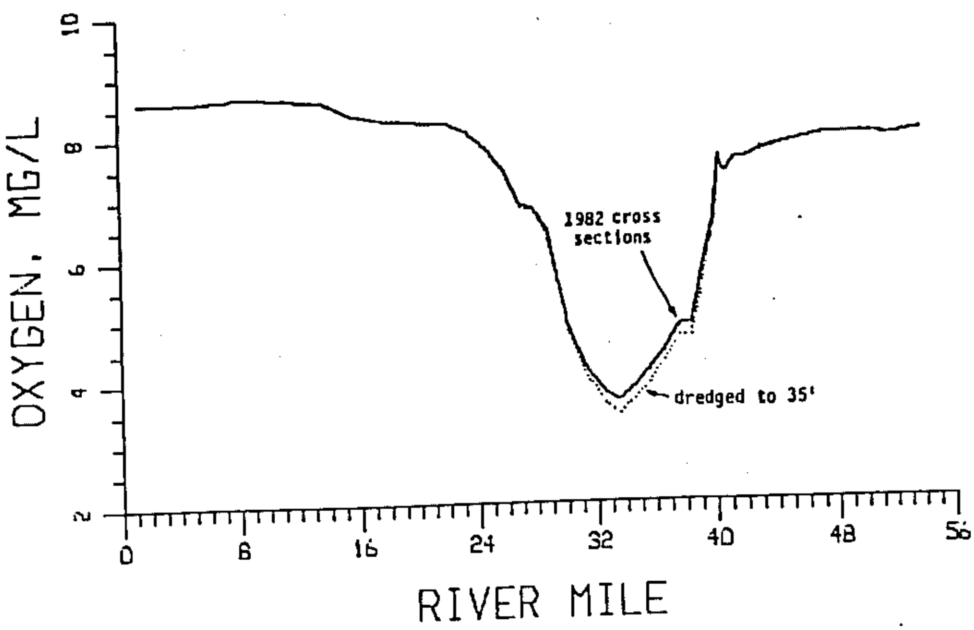


FIGURE V-10. COMPUTED DAILY MEAN DISSOLVED OXYGEN PROFILE WITH THE 1982 SHIP CHANNEL CROSS SECTION TRUNCATED AT 30 FEET AND DEEPENED TO 35 FEET

September 26, 1974



October 10, 1978

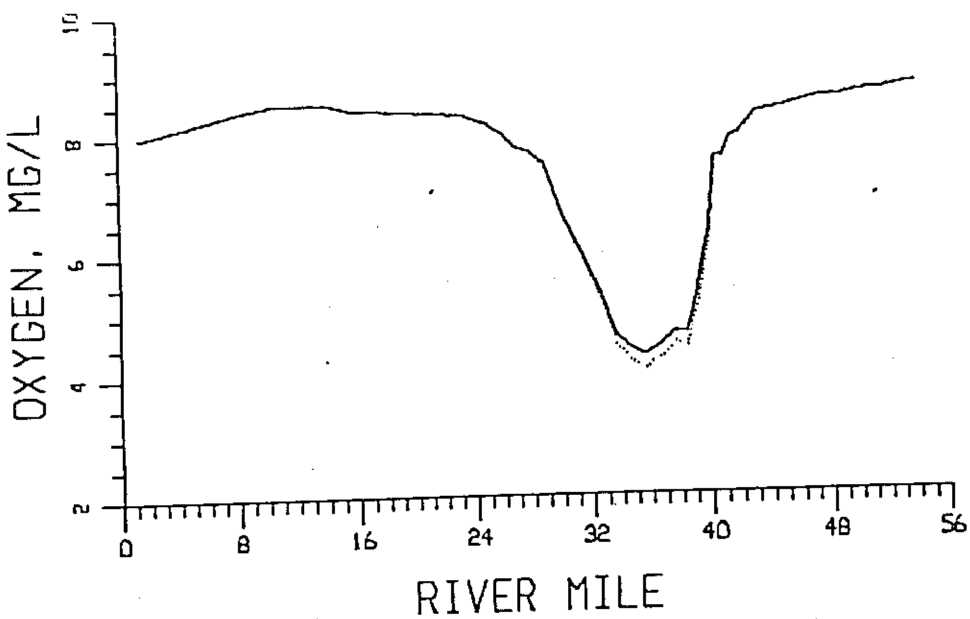


FIGURE V-11. COMPUTED DAILY MEAN DISSOLVED OXYGEN PROFILE WITH THE 1982 SHIP CHANNEL CROSS SECTION AND THE 35 FOOT DREDGED CHANNEL

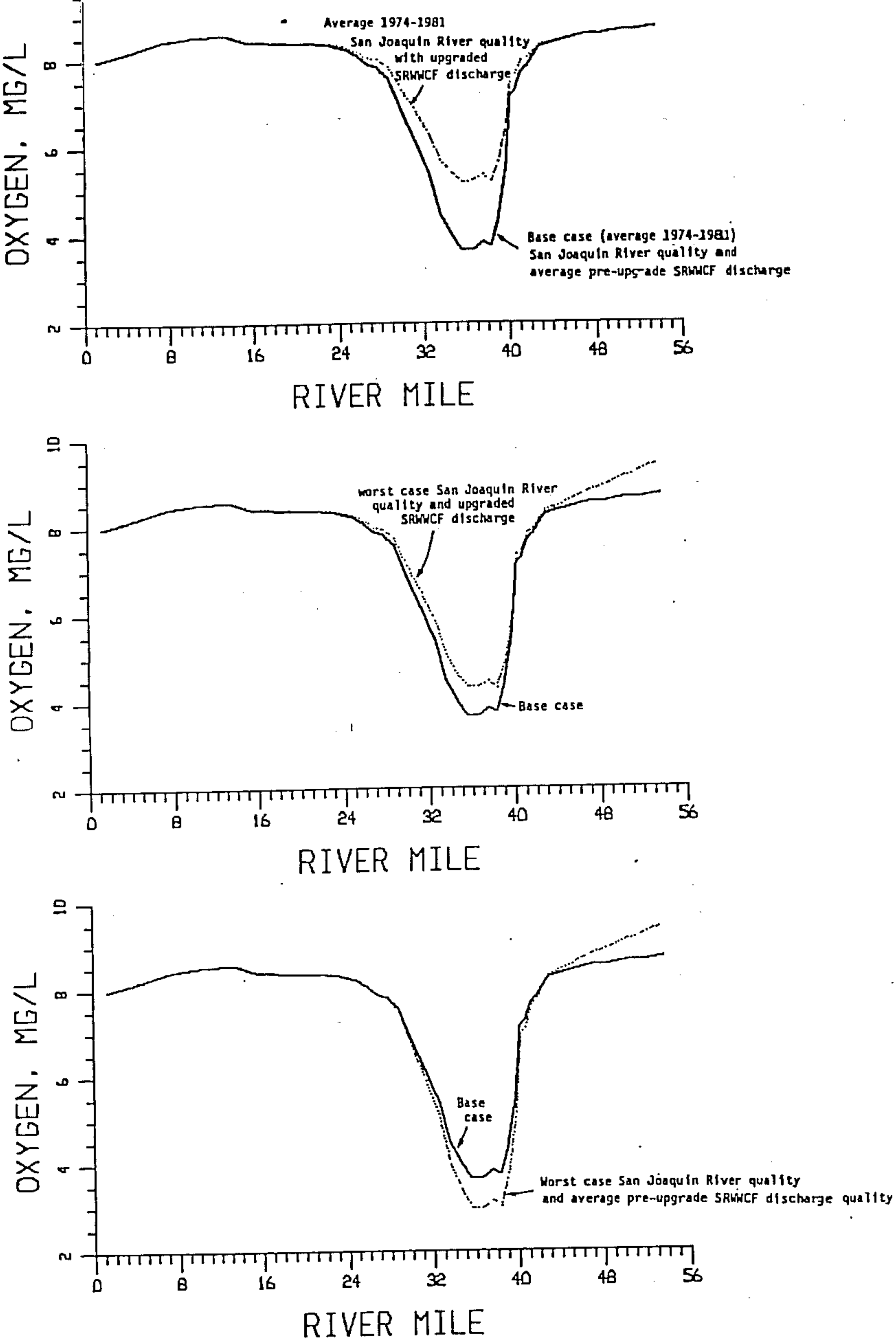
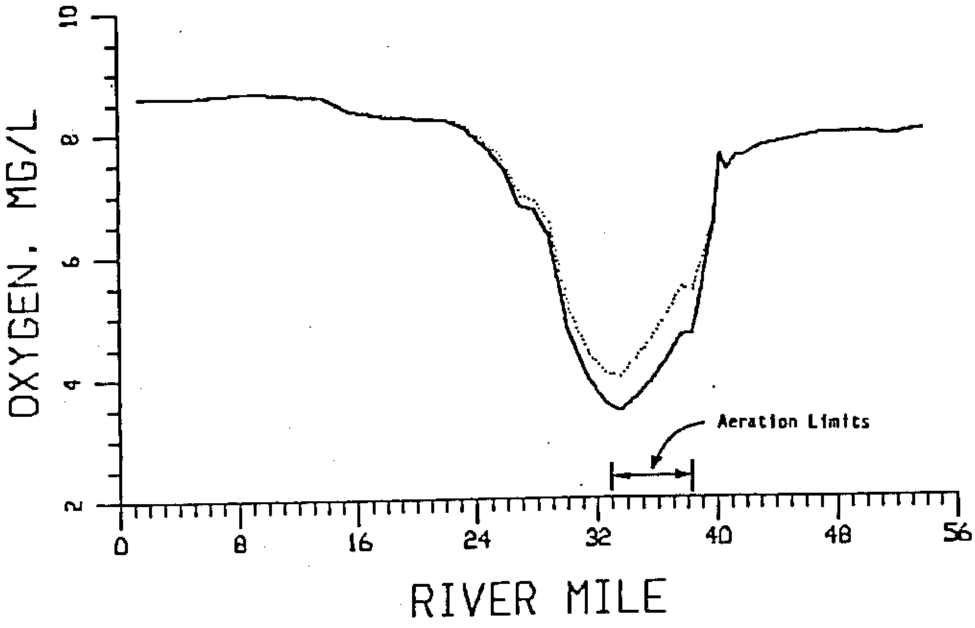


FIGURE V-12. SIMULATED DAILY MEAN DISSOLVED OXYGEN CONCENTRATIONS WITHIN THE SAN JOAQUIN RIVER AND SHIP CHANNEL UNDER VARIOUS INFLOW AND SRWWCF DISCHARGE QUALITY

September 26, 1974



October 10, 1978

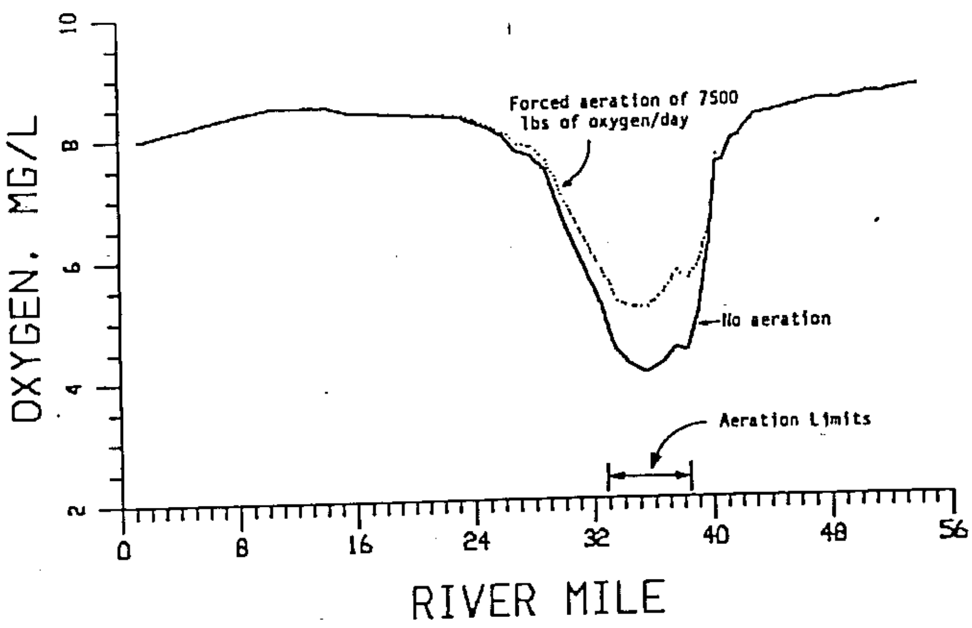


FIGURE V-13. EFFECTS OF ADDING 7500 POUNDS OF OXYGEN DAILY TO THE STOCKTON SHIP CHANNEL BETWEEN RIVER MILES 33 AND 38 UNDER POST DREDGING 1982 CHANNEL GEOMETRY

REFERENCES

1. Smith, Donald J., "Users Guide for the Stockton Ship Channel Project Link-Node Hydrodynamic Model", Resource Management Associates, Inc., February, 1984.

2. Lerseth, Richard, "Delta Hydrodynamic Operations Model", Department of Water Resources of California, June 1976.

3. "Dayflow Summary, Water Years 1955 Through 1980", Central District, California State Department of Water Resources, February, 1982.

4. Zison, S. W., et al., "Rates, Constants and Kinetics Formulations in Surface Water Quality Modeling", Tetra Tech, Inc., Technical Report prepared for the Environmental Protection Agency, Athens, Georgia, December 1978.

5. Collins, C. D. and J. H. Wlosinski, Coefficients for use in the U.S. Army Corps of Engineers Reservoir Model, CE-QUAL-R1, Environmental Laboratory, U.S. Army Engineers, Waterways Experiment Station, Vicksburg, Mississippi, October 1983.

6. Smith, D. J., "Water Quality for River-Reservoir Systems", Resource Management Associates, computer program description prepared for the U.S. Army Corps of Engineers, the Hydrologic Engineering Center, Davis, California, October 1978.

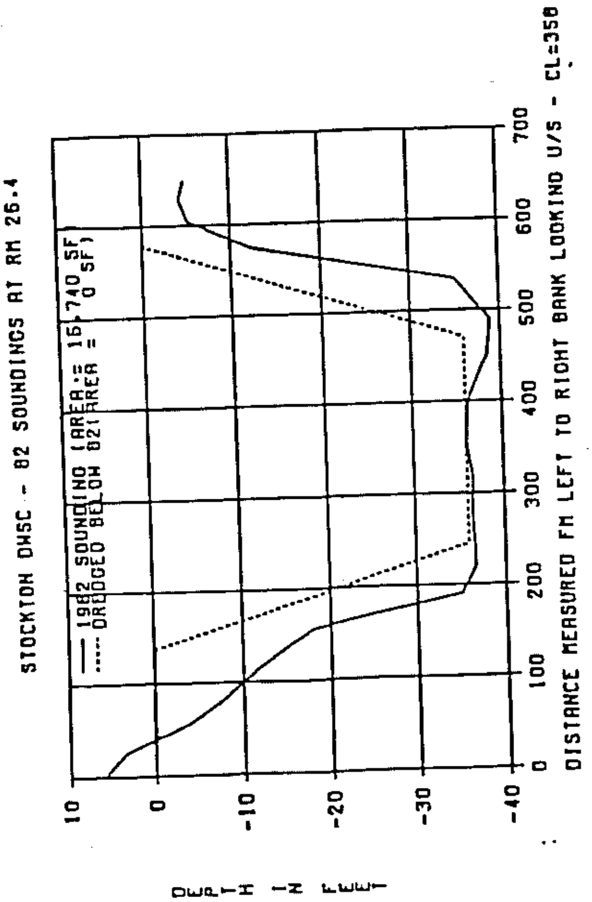
7. U.S. Environmental Protection Agency, "The Effects of Channel Deepening on Water Quality Factors in the San Joaquin River near Stockton, California", December 1971.

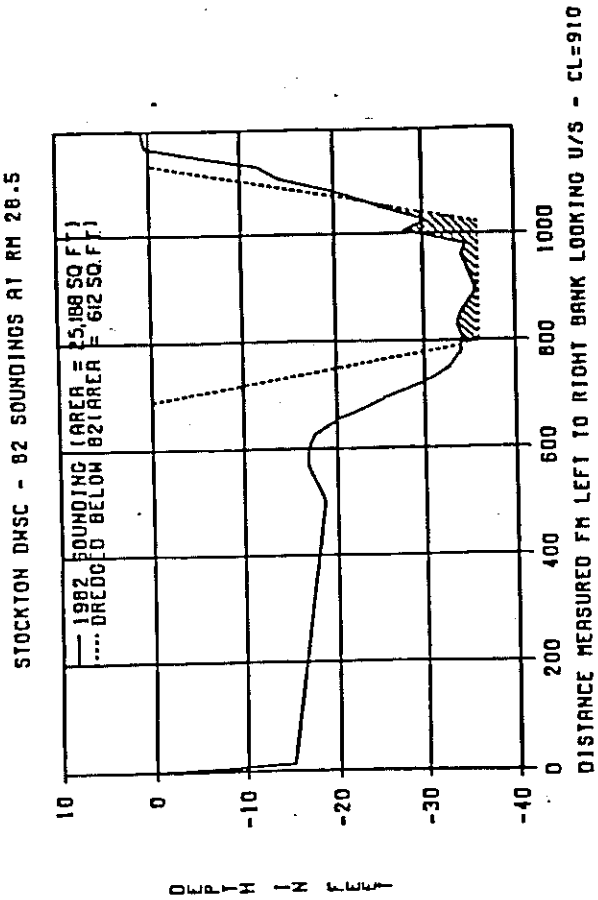
8. 1974 Old River Closure, California State Department of Water Resources.

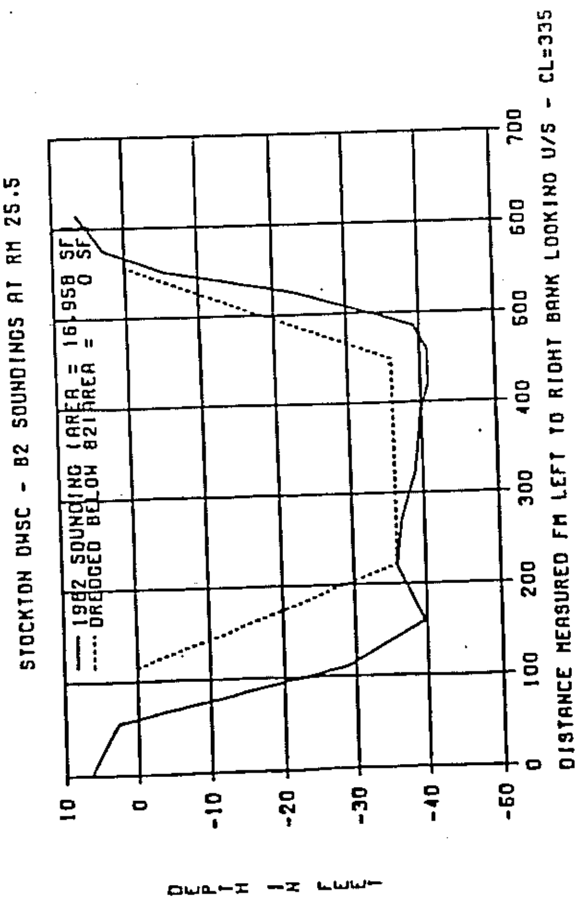
9. 1978 Dissolved Oxygen Field Study, California State Department of Water Resources.

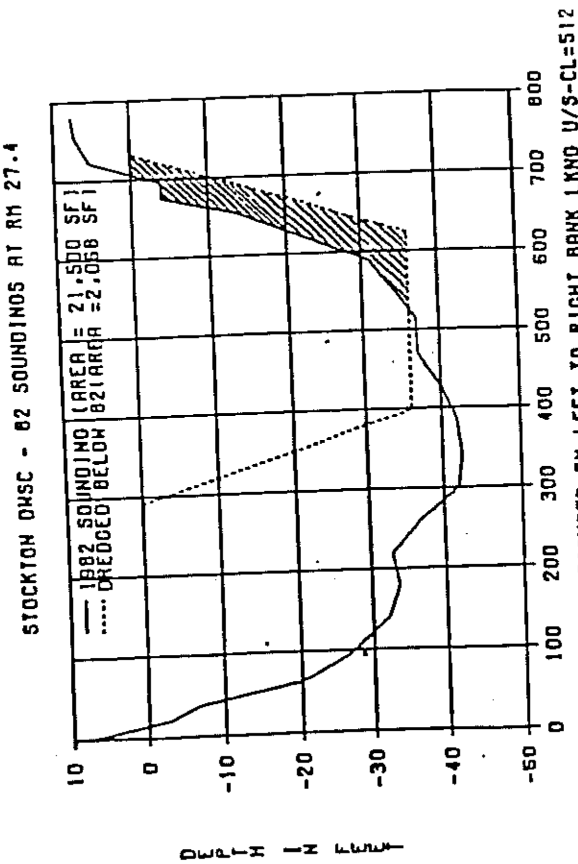
APPENDIX A

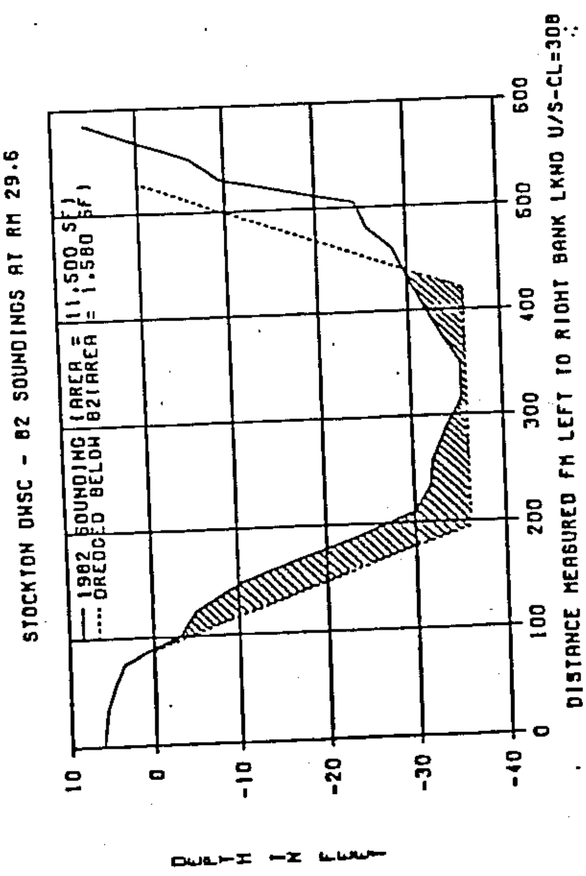
STOCKTON SHIP CHANNEL CROSS SECTIONS DERIVED FROM 1977 AND 1982 SOUNDINGS

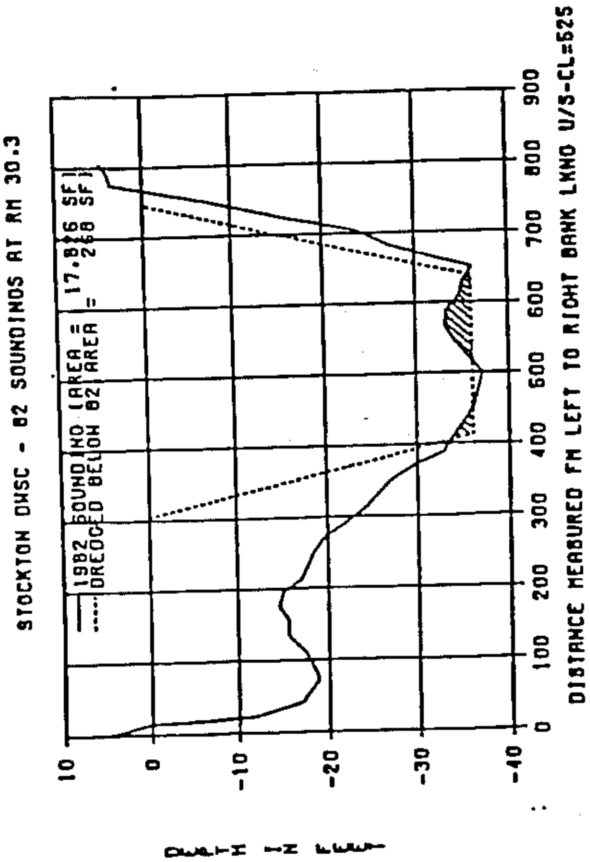

STOCKTON DWSC - 82 SOUNDINGS AT RM 26.4
1982 SOUNDING (AREA = 16,740 SF)
DREDGED BELOW 82 (AREA = 0 SF)
DISTANCE MEASURED FM LEFT TO RIGHT BANK LOOKING U/S - CL=358
DEPTH IN FEET

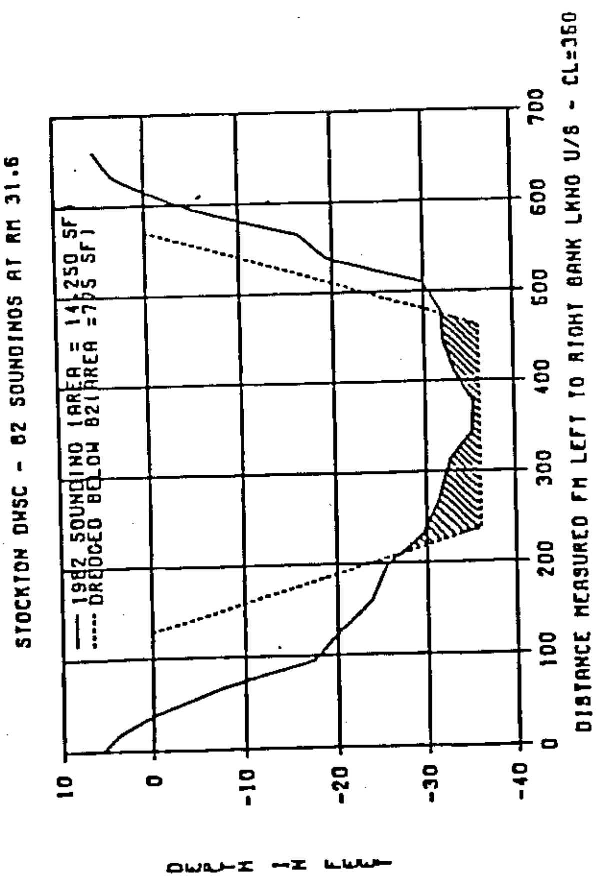

STOCKTON DWSC - 82 SOUNDINGS AT RM 28.5
1982 SOUNDING (AREA = 25,188 SQ FT)
DREDGED BELOW 82 (AREA = 612 SQ FT)
DISTANCE MEASURED FM LEFT TO RIGHT BANK LOOKING U/S - CL=910
DEPTH IN FEET

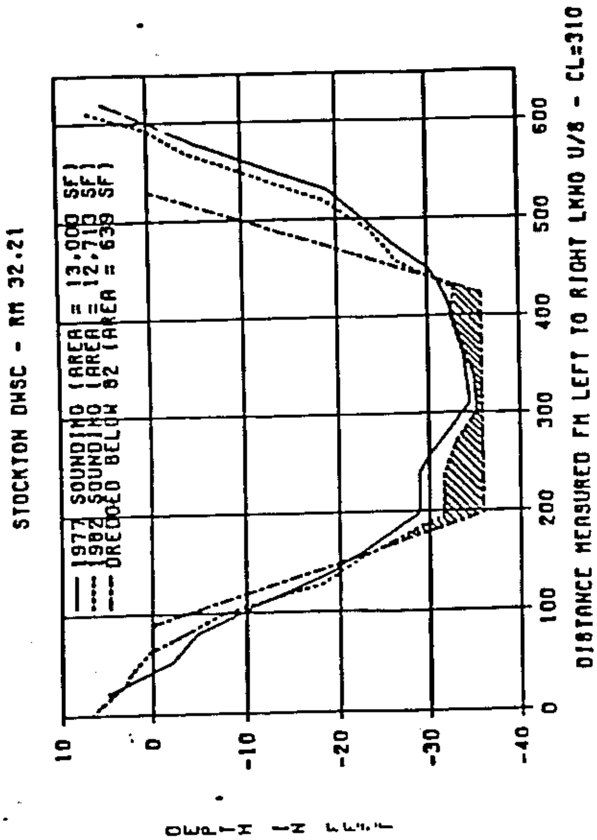

STOCKTON DWSC - 82 SOUNDINGS AT RM 25.5
1982 SOUNDING (AREA = 16,958 SF)
DREDGED BELOW 82 (AREA = 0 SF)
DISTANCE MEASURED FM LEFT TO RIGHT BANK LOOKING U/S - CL=335
DEPTH IN FEET

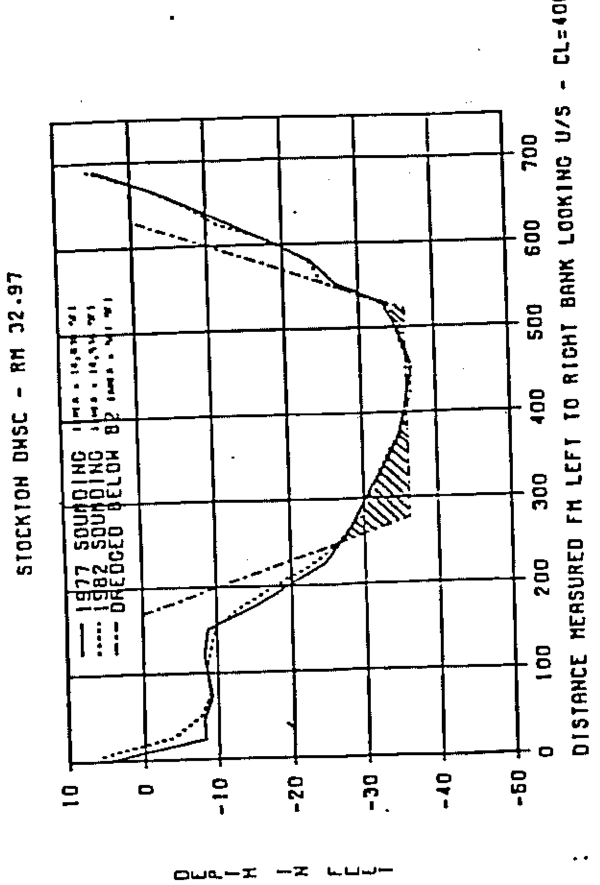

STOCKTON DWSC - 82 SOUNDINGS AT RM 27.4
1982 SOUNDING (AREA = 21,500 SF)
DREDGED BELOW 82 (AREA = 2,058 SF)
DISTANCE MEASURED FM LEFT TO RIGHT BANK LKNG U/S-CL=512
DEPTH IN FEET

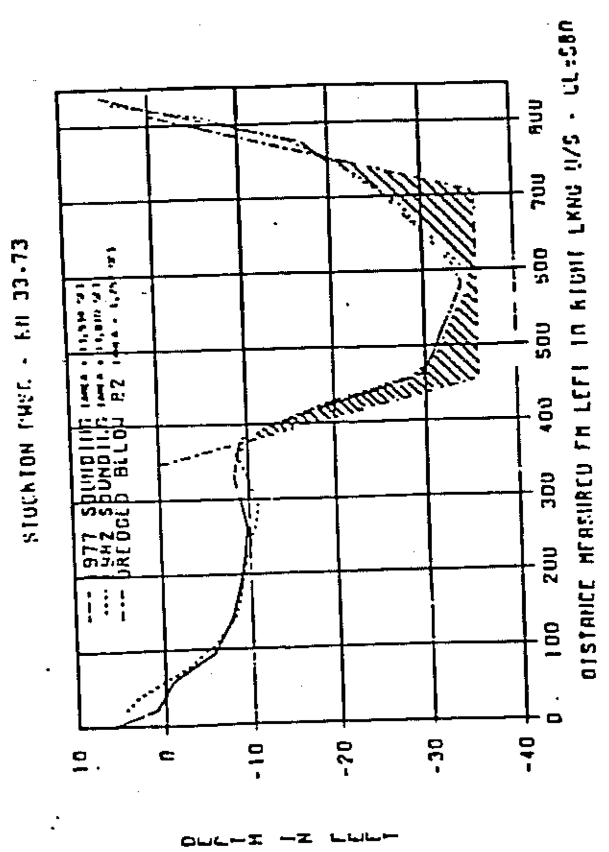

STOCKTON DWSC - 82 SOUNDINGS AT RM 29.6
1982 SOUNDING (AREA = 11,500 SF)
DREDGED BELOW 82(AREA = 1,580 SF)
DISTANCE MEASURED FM LEFT TO RIGHT BANK LKNG U/S-CL=308

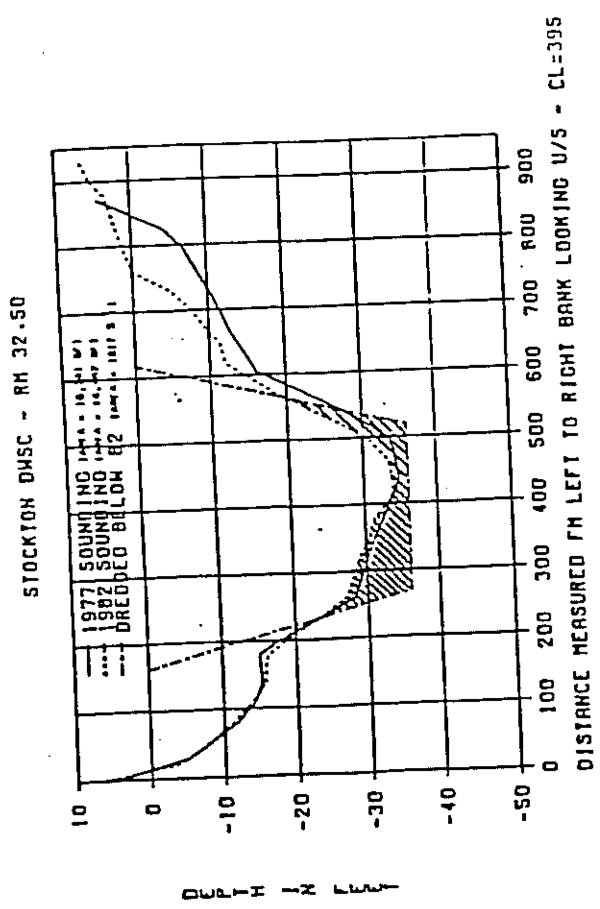

STOCKTON DWSC - 82 SOUNDINGS AT RM 30.3
1982 SOUNDING (AREA =
DREDGED BELOW 82(AREA = 268 SF)
DISTANCE MEASURED FM LEFT TO RIGHT BANK LKNG U/S-CL=525

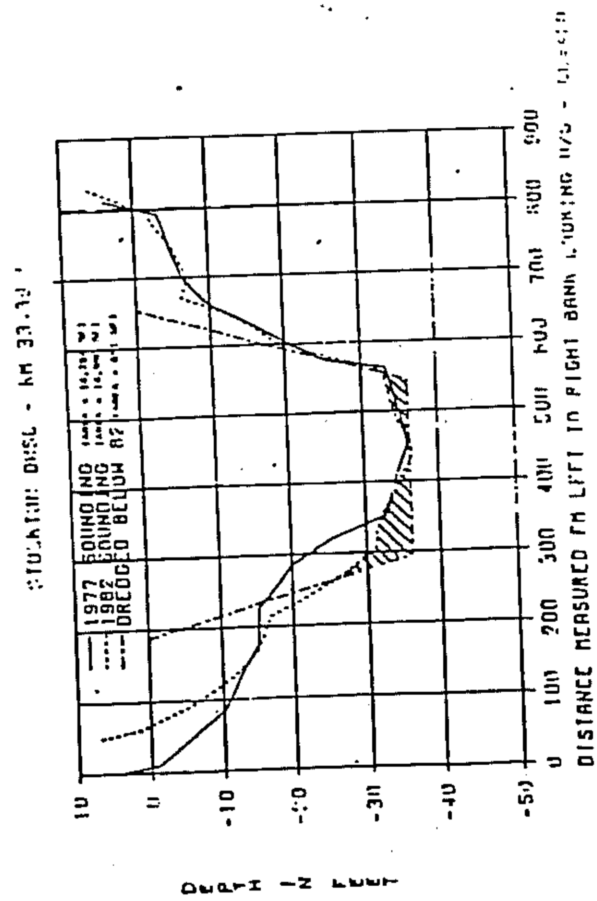

STOCKTON DWSC - 82 SOUNDINGS AT RM 31.6
1982 SOUNDING (AREA = 14,250 SF)
DREDGED BELOW 82(AREA =
DISTANCE MEASURED FM LEFT TO RIGHT BANK LKNG U/S - CL=360

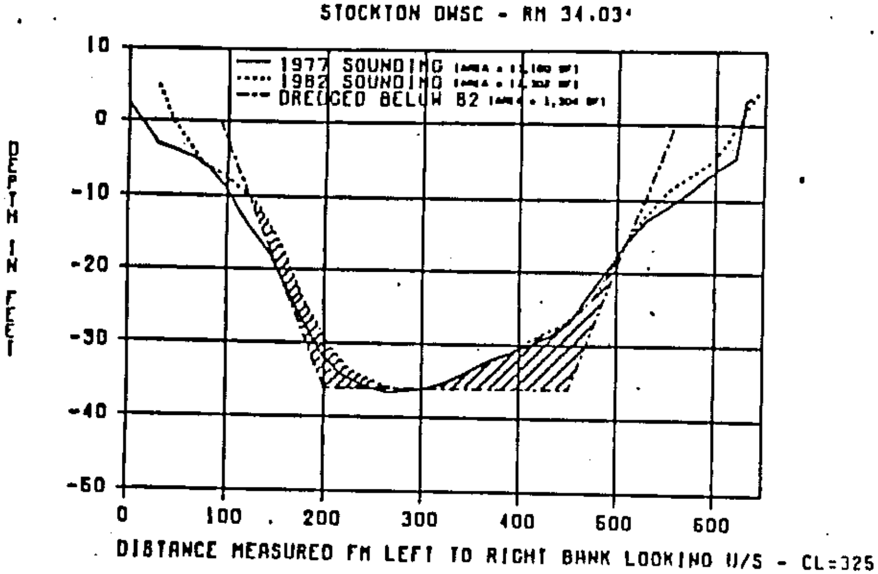

STOCKTON DWSC - RM 32.21
1977 SOUNDING (AREA = 13,000 SF)
1982 SOUNDING (AREA = 12,710 SF)
DREDGED BELOW 82 (AREA = 639 SF)
DISTANCE MEASURED FM LEFT TO RIGHT LKNG U/S - CL=310

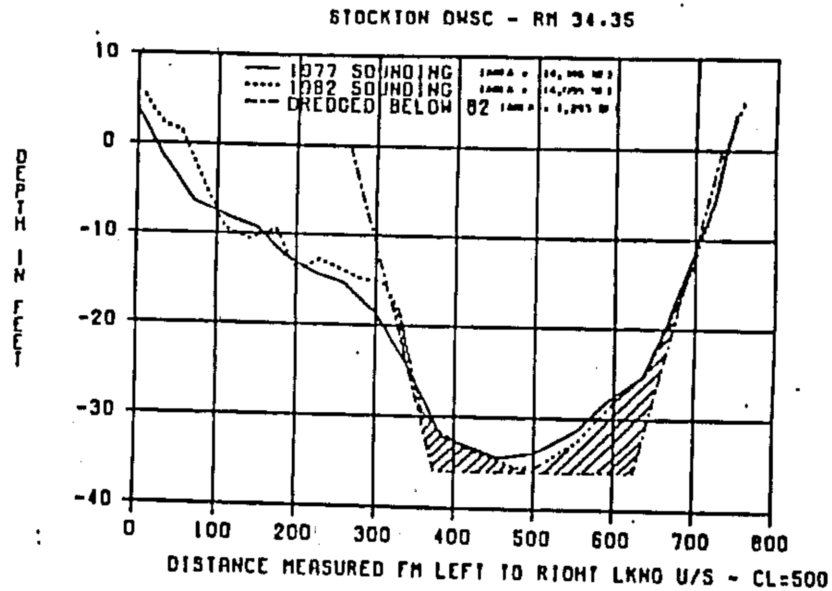

STOCKTON DWSC - RM 32.97
1977 SOUNDING
1982 SOUNDING
DREDGED BELOW 82
DISTANCE MEASURED FM LEFT TO RIGHT BANK LOOKING U/S - CL=400
DEPTH IN FEET

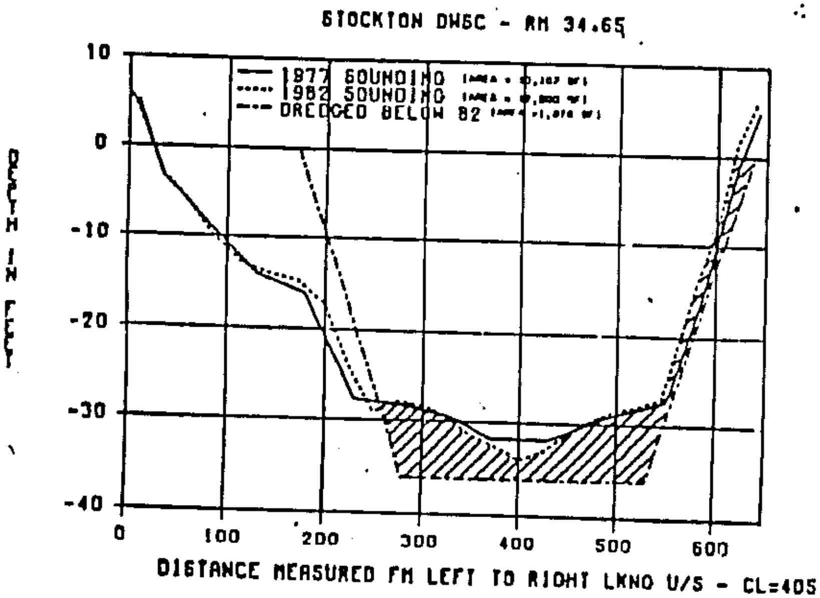

977 SOUNDING
DREDGED BELOW 82
DISTANCE MEASURED FM LEFT TO RIGHT LKNG U/S

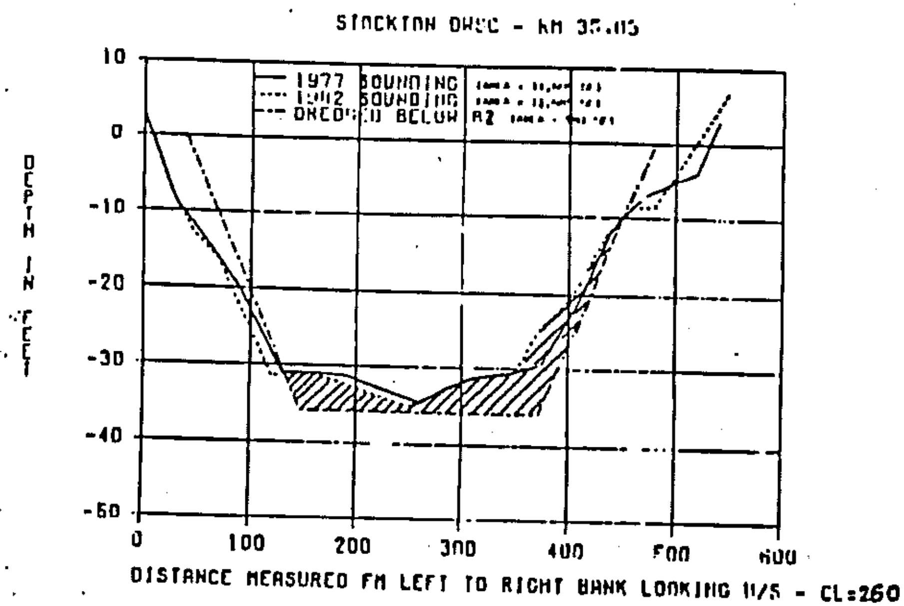

STOCKTON DWSC - RM 32.50
1977 SOUNDING
1982 SOUNDING
DREDGED BELOW 82
DISTANCE MEASURED FM LEFT TO RIGHT BANK LOOKING U/S - CL=395
DEPTH IN FEET

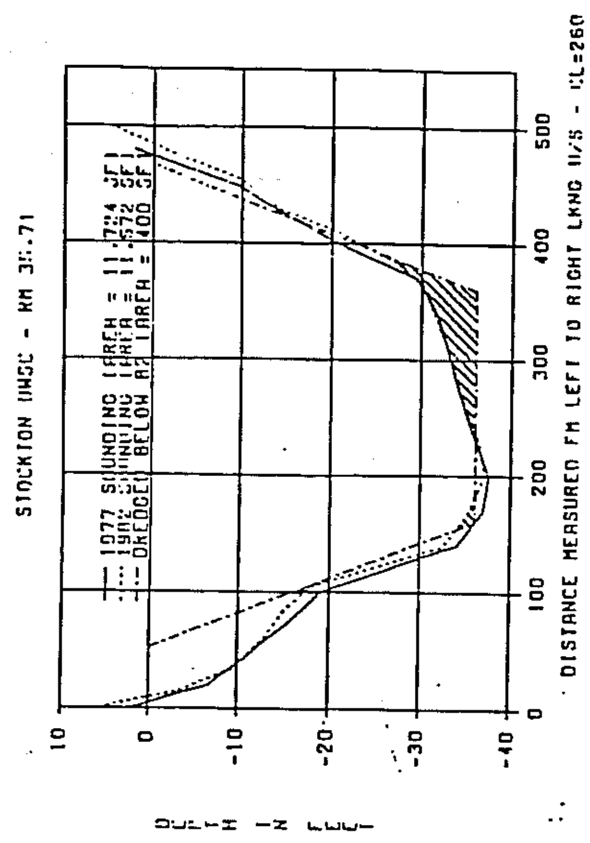

1977 SOUNDING
1982 SOUNDING
DREDGED BELOW 82
DISTANCE MEASURED FM LEFT TO RIGHT BANK

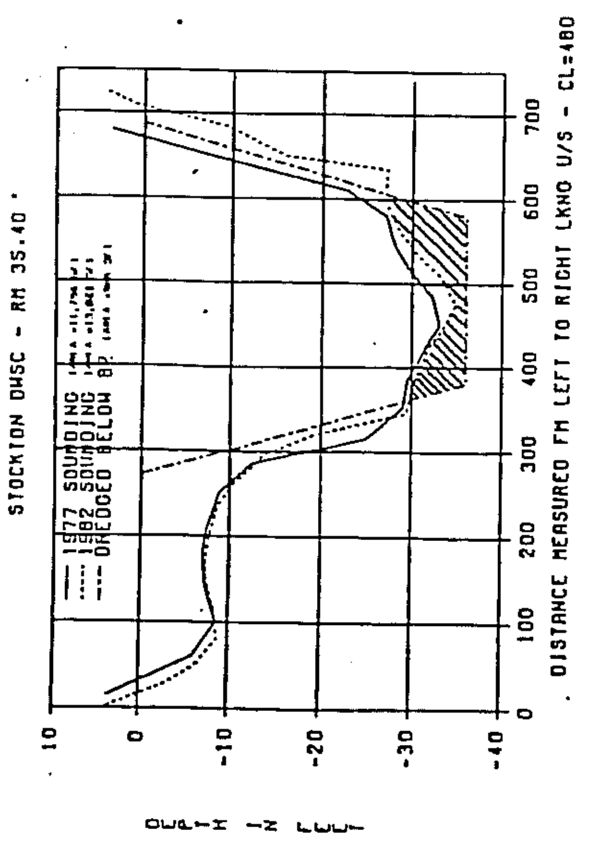

STOCKTON DWSC - RM 34.03
1977 SOUNDING
1982 SOUNDING
DREDGED BELOW 82
DEPTH IN FEET
DISTANCE MEASURED FM LEFT TO RIGHT BANK LOOKING U/S - CL=325

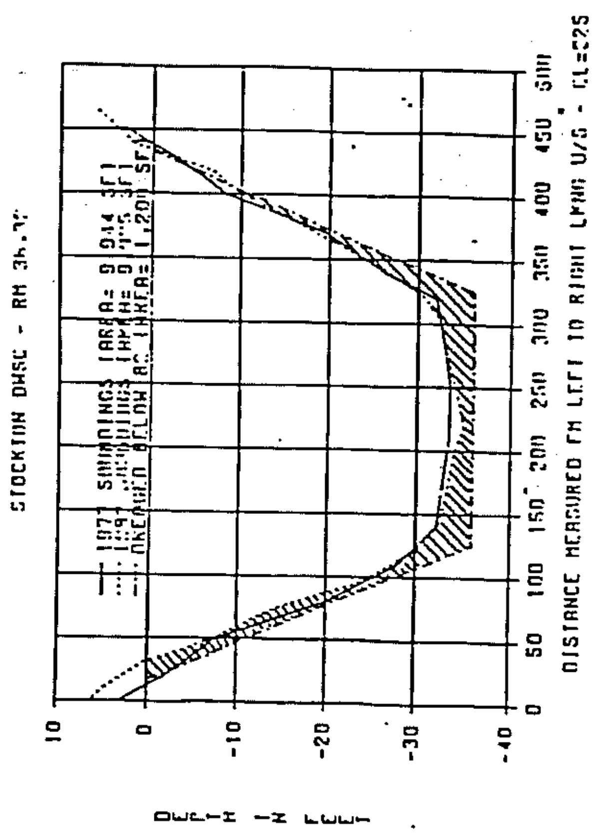

STOCKTON DWSC - RM 34.35
1977 SOUNDING
1982 SOUNDING
DREDGED BELOW 82
DEPTH IN FEET
DISTANCE MEASURED FM LEFT TO RIGHT LKNG U/S - CL=500

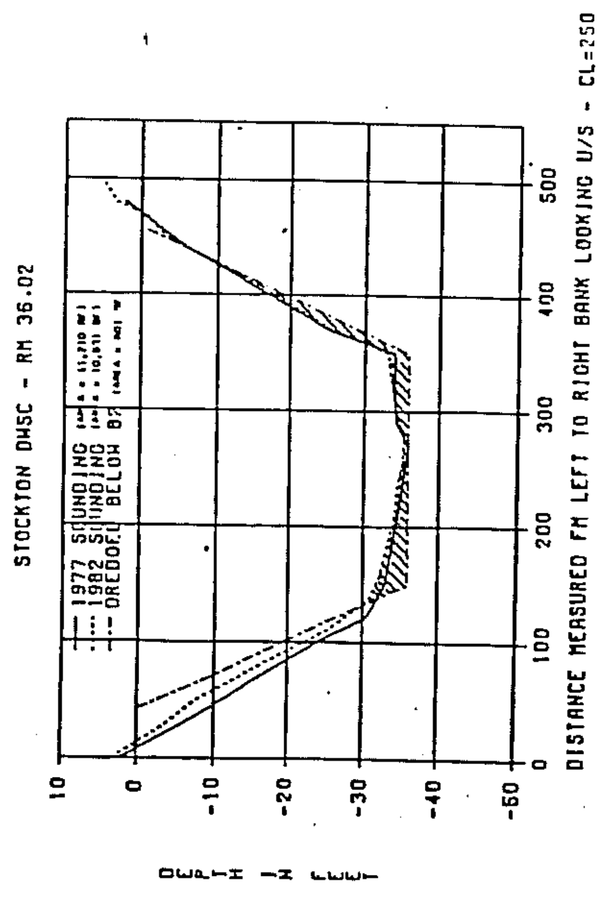

STOCKTON DWSC - RM 34.65
1977 SOUNDING
1982 SOUNDING
DREDGED BELOW 82
DEPTH IN FEET
DISTANCE MEASURED FM LEFT TO RIGHT LKNG U/S - CL=405

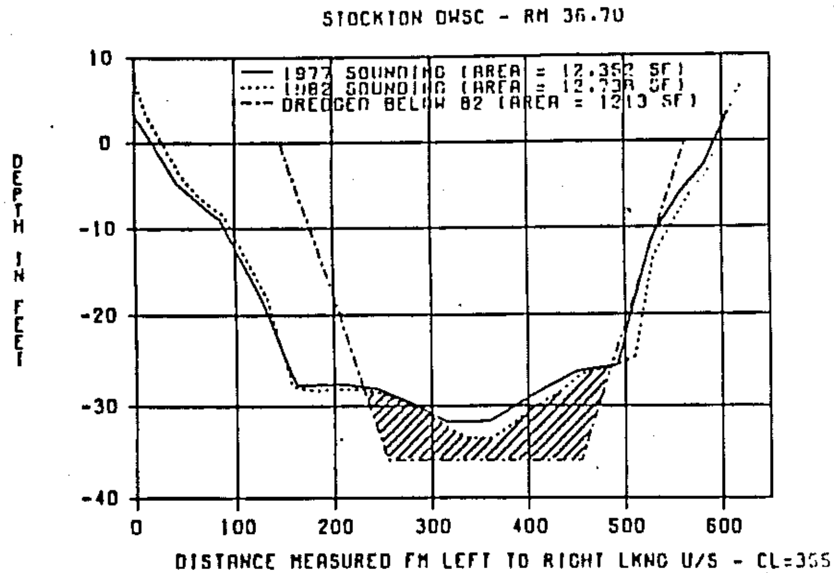

1977 SOUNDING
DEPTH IN FEET
DISTANCE MEASURED FM LEFT TO RIGHT BANK LOOKING U/S - CL=260

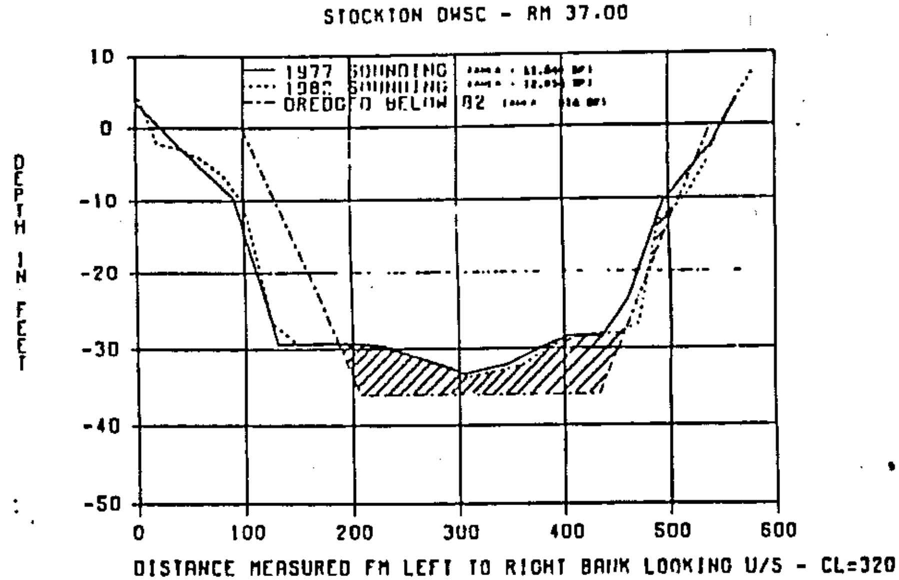

STOCKTON DWSC - RM 35.71
1977 SOUNDING (AREA = 11,724 SF)
1982 SOUNDING (AREA = 11,572 SF)
DREDGED BELOW 82 (AREA = 400 SF)
DEPTH IN FEET
DISTANCE MEASURED FM LEFT TO RIGHT LKNG U/S - CL=260

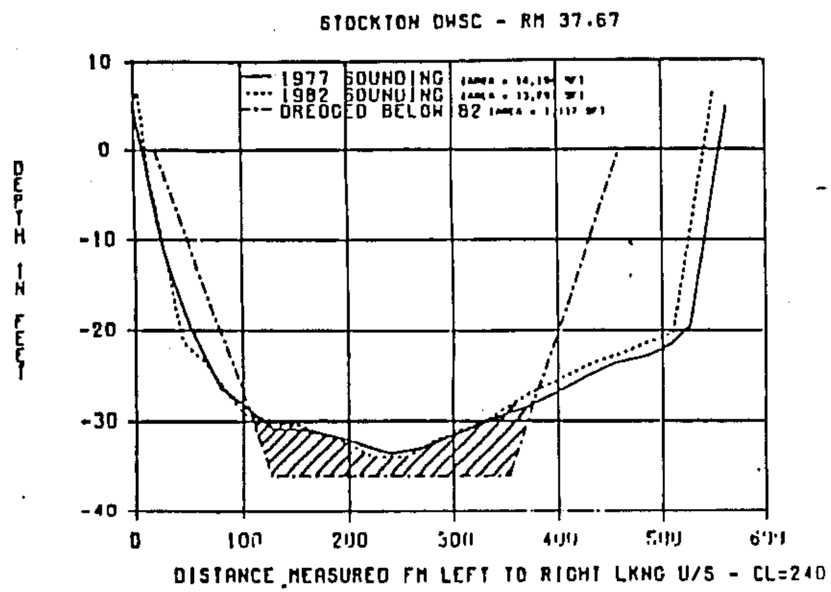

STOCKTON DWSC - RM 35.40
1977 SOUNDING
1982 SOUNDING
DREDGED BELOW 82
DEPTH IN FEET
DISTANCE MEASURED FM LEFT TO RIGHT LKNG U/S - CL=480

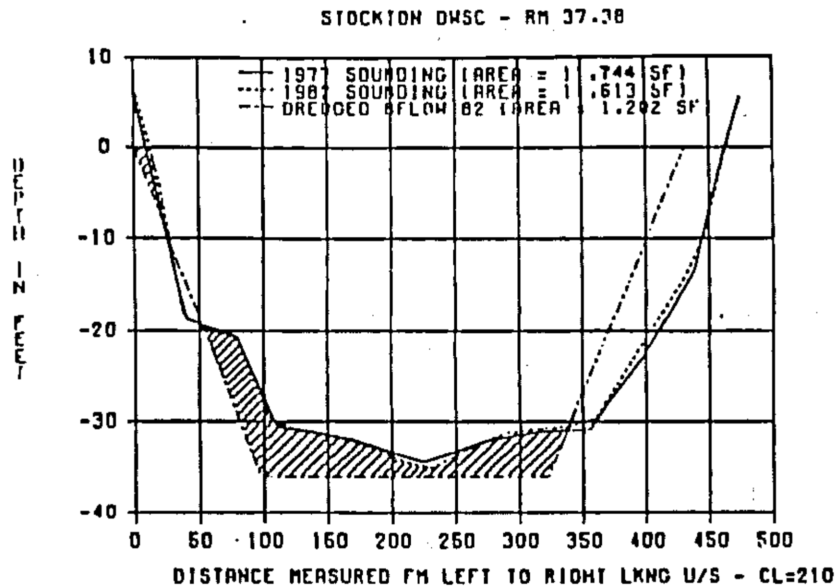

STOCKTON DWSC - RM
1977 SOUNDINGS
DREDGED BELOW 82
DEPTH IN FEET
DISTANCE MEASURED FM LEFT TO RIGHT LKNG U/S - CL=225

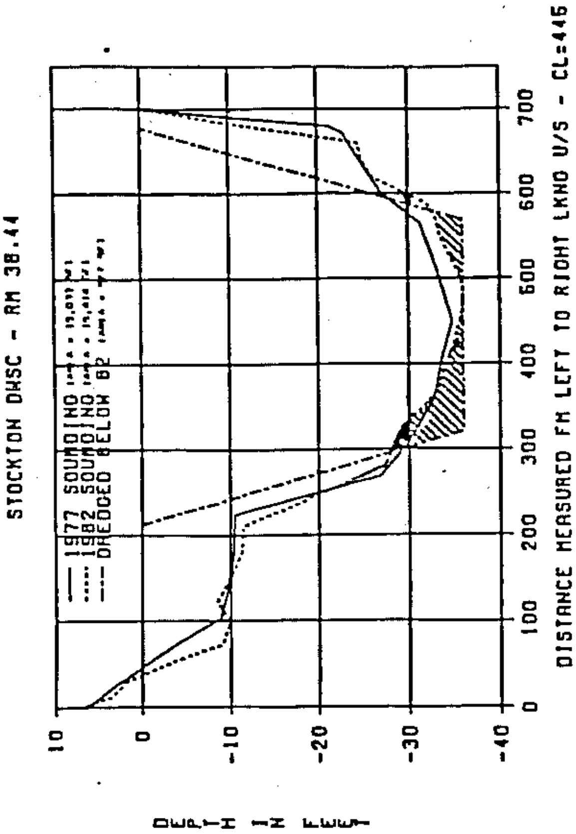

STOCKTON DWSC - RM 36.02
1977 SOUNDING
1982 SOUNDING
DREDGED BELOW 82
DEPTH IN FEET
DISTANCE MEASURED FM LEFT TO RIGHT BANK LOOKING U/S - CL=250

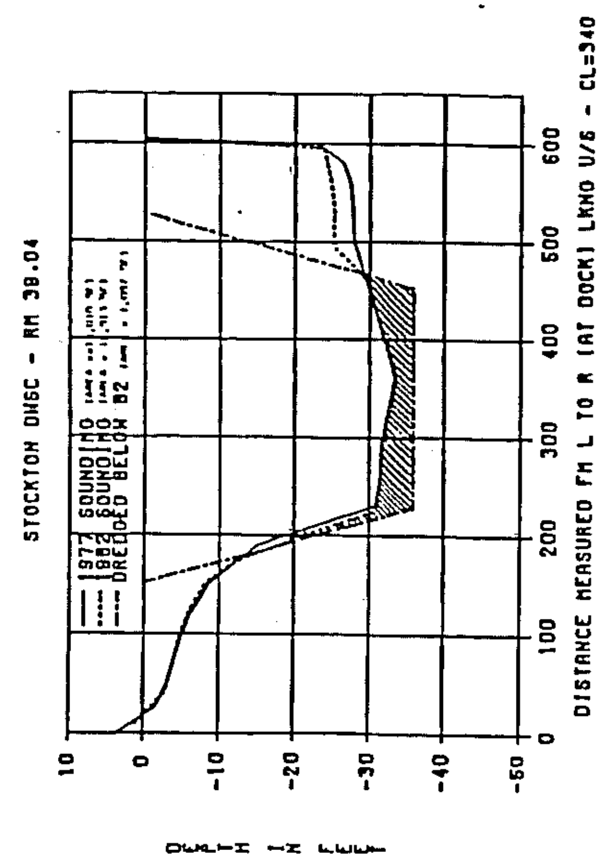

STOCKTON DWSC - RM 36.70
1977 SOUNDING (AREA = 12,352 SF)
1982 SOUNDING (AREA = 12,738 SF)
DREDGED BELOW 82 (AREA = 1213 SF)
DEPTH IN FEET
10
0
-10
-20
-30
-40
0
100
200
300
400
500
600
DISTANCE MEASURED FM LEFT TO RIGHT LKNG U/S - CL=355

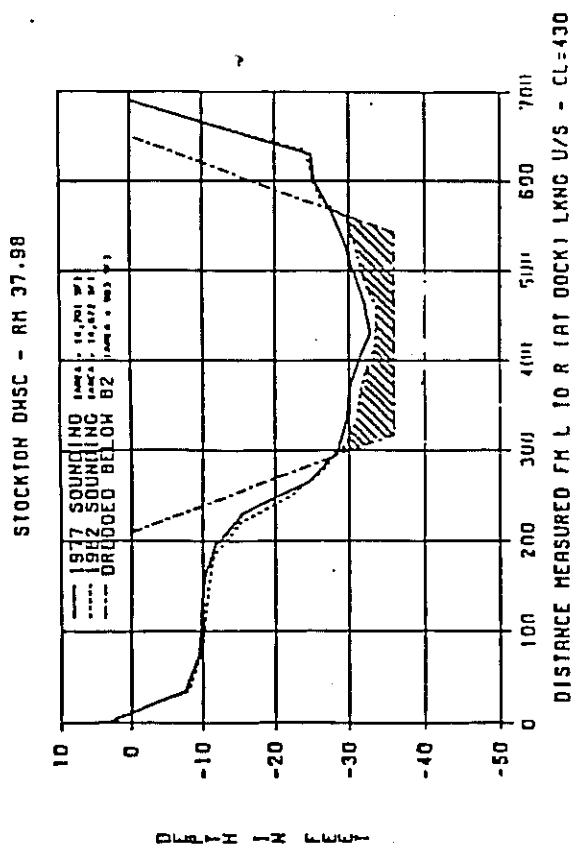

STOCKTON DWSC - RM 37.00
1977 SOUNDING
1982 SOUNDING
DREDGED BELOW 82
DEPTH IN FEET
10
0
-10
-20
-30
-40
-50
0
100
200
300
400
500
600
DISTANCE MEASURED FM LEFT TO RIGHT BANK LOOKING U/S - CL=320

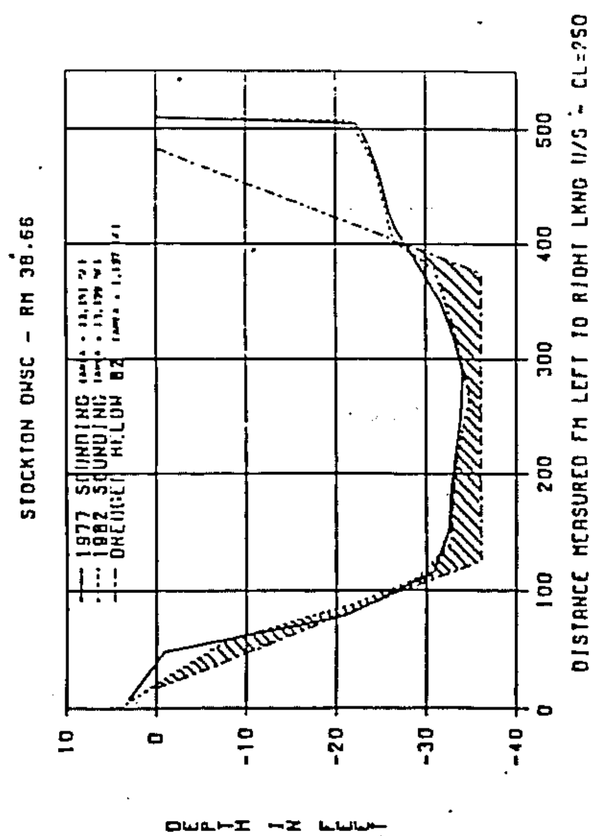

STOCKTON DWSC - RM 37.67
1977 SOUNDING
1982 SOUNDING
DREDGED BELOW 82
DEPTH IN FEET
10
0
-10
-20
-30
-40
0
100
200
300
400
500
600
DISTANCE MEASURED FM LEFT TO RIGHT LKNG U/S - CL=240


STOCKTON DWSC - RM 37.38
1977 SOUNDING (AREA = 11,744 SF)
1982 SOUNDING (AREA = 11,613 SF)
DREDGED BELOW 82 (AREA = 1,202 SF)
DEPTH IN FEET
10
0
-10
-20
-30
-40
0
50
100
150
200
250
300
350
400
450
500
DISTANCE MEASURED FM LEFT TO RIGHT LKNG U/S - CL=210

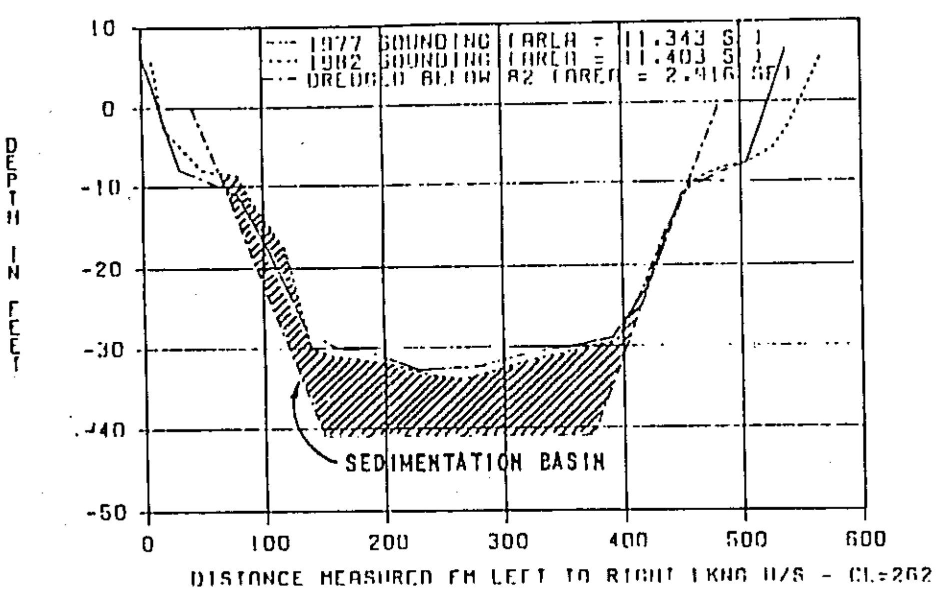

STOCKTON DWSC - RM 38.44
1977 SOUNDING
1982 SOUNDING
DREDGED BELOW 82
DISTANCE MEASURED FM LEFT TO RIGHT LKNG U/S - CL=445
DEPTH IN FEET


STOCKTON DWSC - RM 39.04
1977 SOUNDING
1982 SOUNDING
DREDGED BELOW 82
DISTANCE MEASURED FM L TO R (AT DOCK) LKNG U/S - CL=340
DEPTH IN FEET

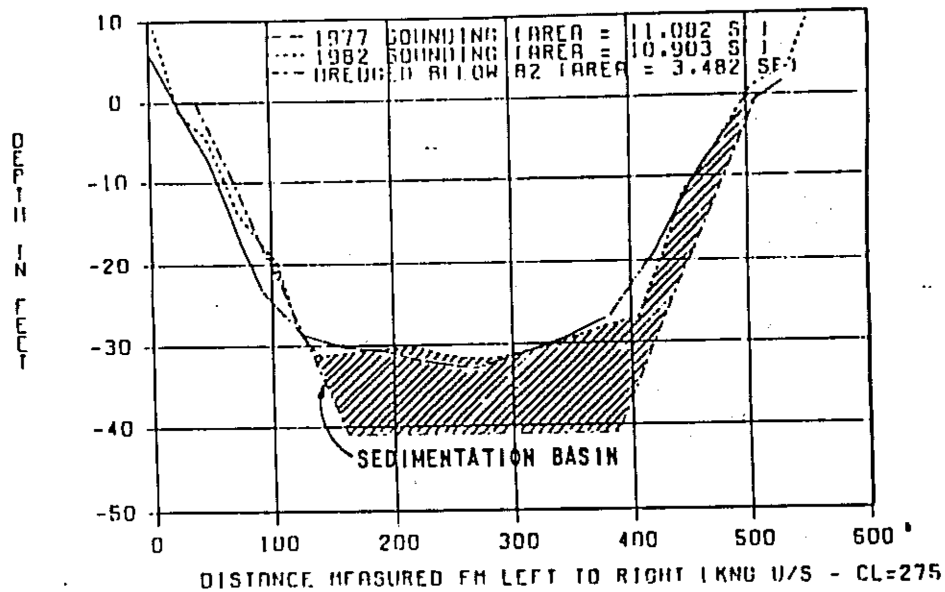

STOCKTON DWSC - RM 37.98
1977 SOUNDING
1982 SOUNDING
DREDGED BELOW 82
DISTANCE MEASURED FM L TO R (AT DOCK) LKNG U/S - CL=430
DEPTH IN FEET


STOCKTON DWSC - RM 38.66
1977 SOUNDING
1982 SOUNDING
DREDGED BELOW 82
DISTANCE MEASURED FM LEFT TO RIGHT LKNG U/S - CL=250
DEPTH IN FEET

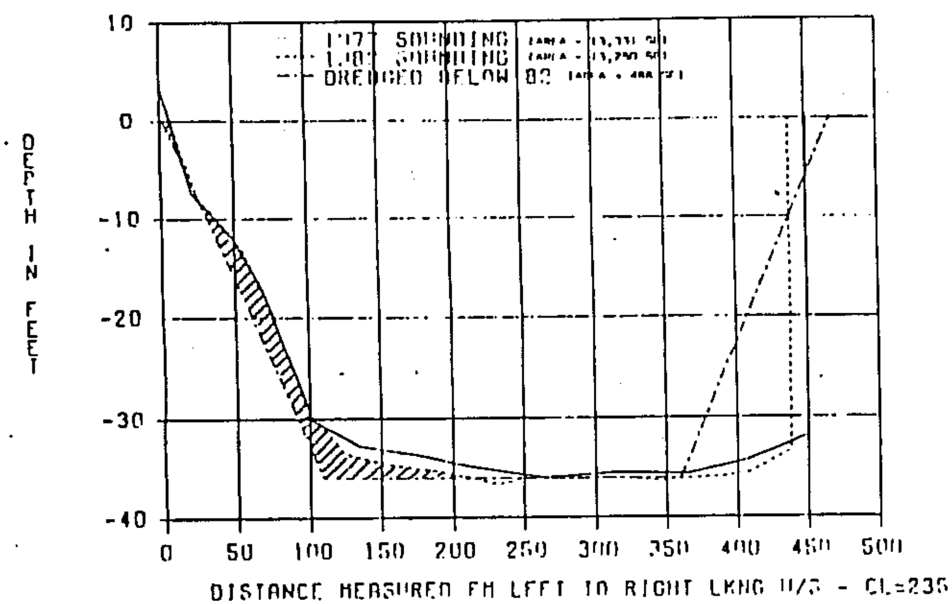
STOCKTON DWSC - RM 39.14



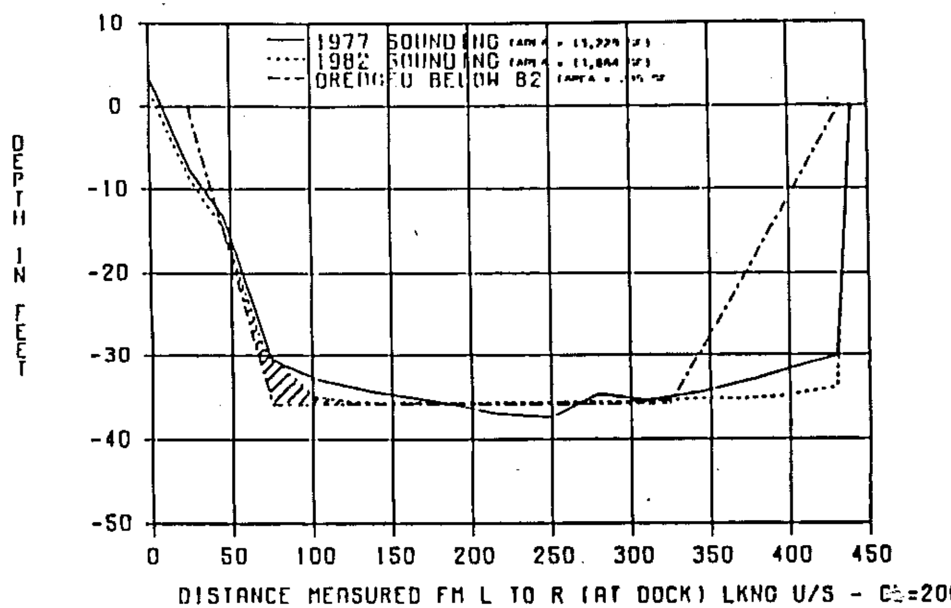
STOCKTON DWSC - RM 39.57

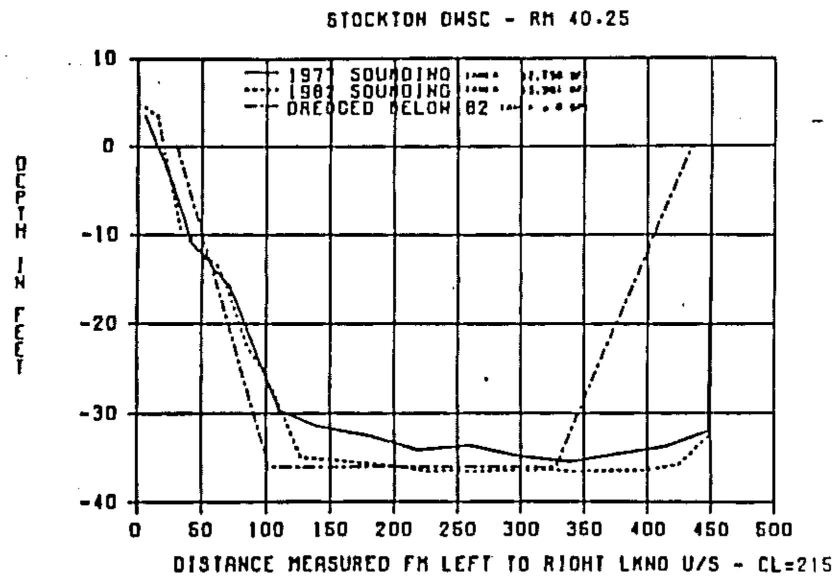


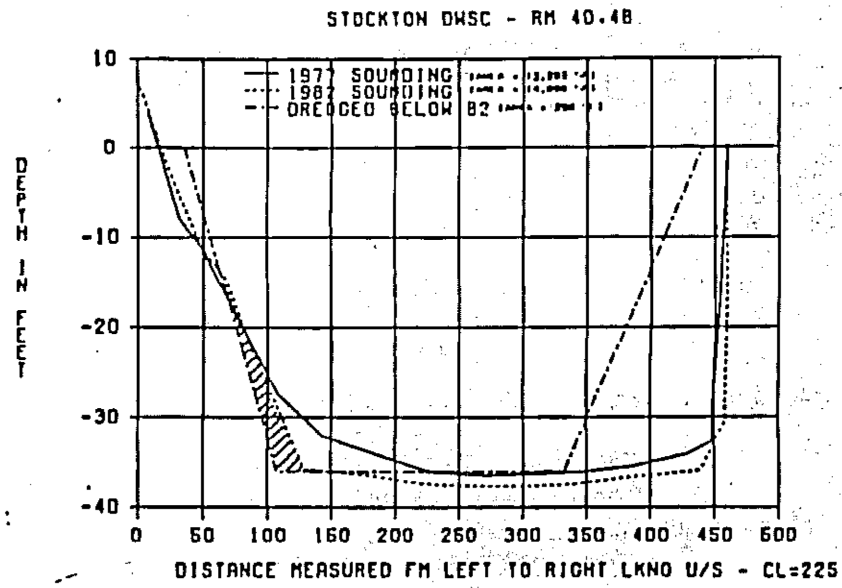
STOCKTON DWSC - RM 39.87

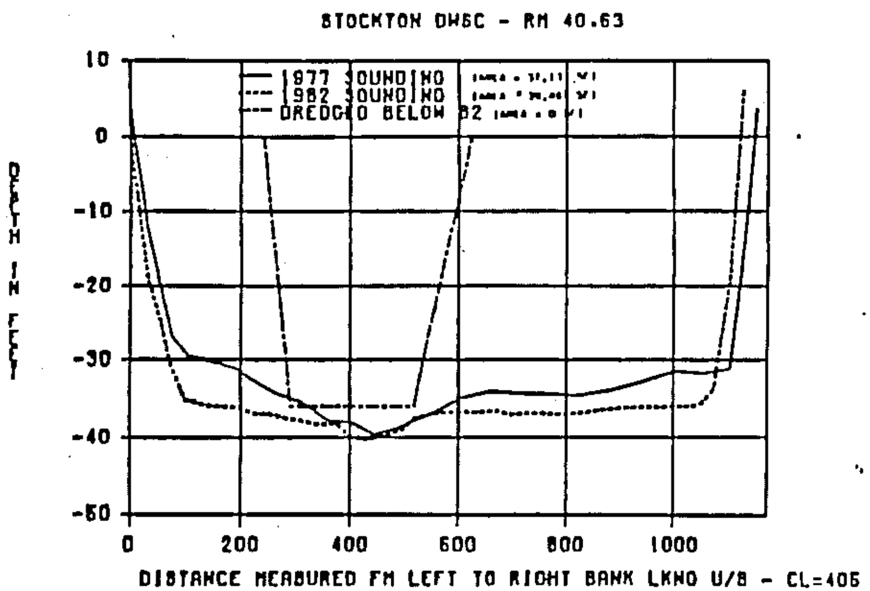


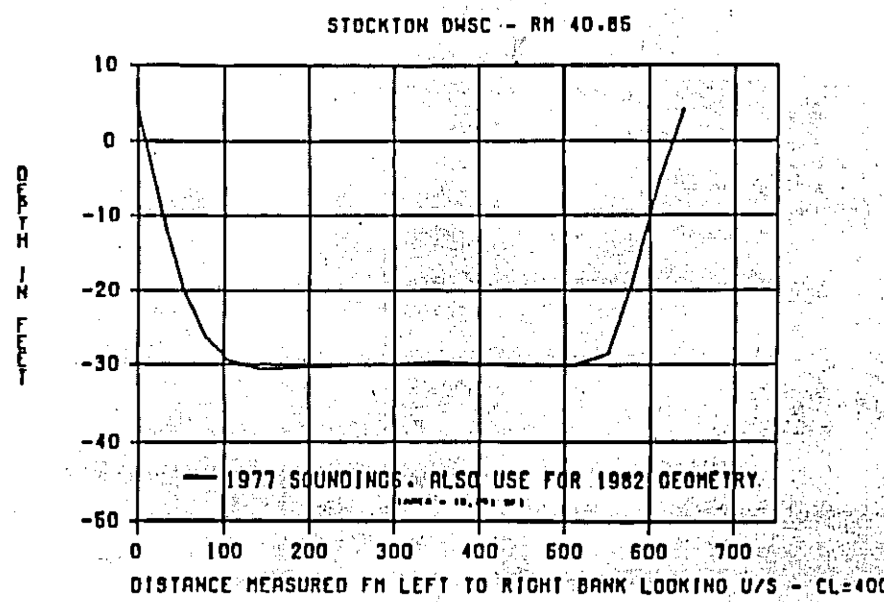
STOCKTON DWSC - RM 40.02




STOCKTON DWSC - RM 40.25
1977 SOUNDING
1982 SOUNDING
DREDGED BELOW 82
DEPTH IN FEET
DISTANCE MEASURED FM LEFT TO RIGHT LKNG U/S - CL=215


STOCKTON DWSC - RM 40.48
1977 SOUNDING
1982 SOUNDING
DREDGED BELOW 82
DEPTH IN FEET
DISTANCE MEASURED FM LEFT TO RIGHT LKNG U/S - CL=225


STOCKTON DWSC - RM 40.63
1977 SOUNDING
1982 SOUNDING
DREDGED BELOW 82
DEPTH IN FEET
DISTANCE MEASURED FM LEFT TO RIGHT BANK LKNG U/S - CL=405


STOCKTON DWSC - RM 40.85
1977 SOUNDINGS. ALSO USE FOR 1982 GEOMETRY
DEPTH IN FEET
DISTANCE MEASURED FM LEFT TO RIGHT BANK LOOKING U/S - CL=400